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Aerospace Corp, El Segundo, Calif Mobile Systems Group

Prepared for

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VOLUME I

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A series of statistical analyses was performed to determine the degree of "correlation" that exists between two specific short tests (STs) and the Federal Emission Certification Test Procedure (FTP) for new vehicles. This work was performed to determine if "reasonable correlation with certification test procedures" exists; this is a condition precedent to the promulgation of regulations that impose the in-use warranty provisions of Sec. 207(b) of the Clean Air Act of 1970 upon the motor vehicle manufacturers.

The basis for the analyses was ST and FTP test data from three 100-vehicle fleets located in (a) Chicago, Illinois, (b) Houston, Texas, and (c) Phoenix, Arizona. Each of the vehicles in these fleets was tested by the FTP, the Federal Short Cycle, and the Federal 3-Mode. Two different statistical analysis methods were used to assess "correlation" -- a conventional correlation analysis, and a contingency table analysis.

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Prepared for

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Office of Air and Waste Management
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Emission Control Technology Division
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FOREWORD

This report, prepared by The Aerospace Corporation for the U. S. Environmental Protection Agency, Emission Control Technology Division, presents the results of a statistical analysis of the degree of correlation between two short tests and the 1975 Federal Test Procedure. The correlation analyses were based on experimental test data from 300 1975-model-year vehicles, composed of three groups of 100 vehicles each that were tested in the cities of Chicago, Houston, and Phoenix.

The results of the study are presented in seven sections. A brief, concise review of important findings and conclusions is presented in the Highlights section. Section 1 contains a summary and discussion of the study results. The background, scope, objectives, and method of approach are given in Section 2. The short tests and test fleet composition are described and discussed in Section 3. Section 4 describes the statistical screening procedures, the primary statistical tools used in the correlation analyses, and the results of the conventional correlation analysis. Similar results of a contingency table analysis for the 300-vehicle fleet are presented in Section 5. Section 6 presents an initial analysis of the emission reductions afforded by implementation of a mandatory inspection and maintenance program using short test cut-points based on (1) a selected error of commission rate for each of three engine displacement groups and (2) an average failure rate for the fleet such as is used in existing I/M programs.

Because of the numerical analysis nature of the study and the many variables addressed, the results of the study are contained in many tables and figures. Therefore, the principal discussion of results is contained in the summary and discussion section; numerous selected tabular information is presented in the summary to facilitate understanding of the stated results.

The voluminous tabular and graphical data are presented in an Appendix of tables and figures. Only Section 1 (the Summary and Discussion) has tabular and graphical data integrated with the text.

ACKNOWLEDGMENT

During the course of this study, Mr. F. P. Hutchins of the Environmental Protection Agency's Emission Control Technology Division, who served as EPA Project Officer for the study, provided valuable guidance and assistance. His efforts are gratefully acknowledged.

Dr. John Thacker was principally responsible for the statistical analysis effort reported herein. The following technical personnel of The Aerospace Corporation also made valuable contributions to the analyses performed under this contract: B. D. Gregoire, A. M. Timmer, D. K. Sakaguchi, and C. A. Vejar.

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HIGHLIGHTS

A series of statistical analyses was performed to determine the degree of "correlation" that exists between two specific short tests (STs) and the Federal Emission Certification Test Procedure (FTP) for new vehicles. This work was performed to determine if "reasonable correlation with certification test procedures" exists; this is a condition precedent to the promulgation of regulations that impose the in-use warranty provisions of Sec. 207(b) of the Clean Air Act of 1970 upon the motor vehicle manufacturers.

The basis for the analyses was ST and FTP test data from three 100-vehicle fleets located in:

Chicago, Illinois
Houston, Texas
Phoenix, Arizona

Each of the vehicles in these fleets was tested by the FTP and the following STs:

Federal Short Cycle
Federal Three-Mode

The first of these STs is a CVS (constant volume sampling) or bag-type test wherein a test technician drives the car on the dynamometer in accordance with a prescribed driving pattern. The vehicle exhaust is diluted by the CVS procedure, and a single sample bag of diluted exhaust is collected for the ST. The latter ST is categorized as modal or volumetric. In this test, the test technician operates the vehicle on a dynamometer at a fixed vehicle speed and dynamometer load, or at idle. The vehicle tailpipe exhaust is sampled directly, and the concentration of each pollutant is measured and recorded. The Federal Three-Mode ST has high-speed, low-speed, and idle modes. The idle mode can be conducted in two ways, (1) idle with transmission in drive (automatic transmission only), or (2) idle in neutral (automatic and manual transmissions).

Hydrocarbon (HC) and carbon monoxide (CO) measurements were recorded with garage-type instruments for the Federal Three-Mode ST. All oxides of nitrogen (NO_x) measurements were made with laboratory analyzers.

Two different statistical analysis methods were used to assess "correlation" -- a conventional correlation analysis, and a contingency table analysis.

The principal results of the study are briefly summarized below. A summary overview and discussion are presented in Section 1, which provides more general statements and findings as well as a detailed discussion and summarization of each study area, as a function of analysis approach.

H-1. SHORT TEST COMPARISONS: 300-VEHICLE FLEET AVERAGES[1]

a. The Federal Short Cycle exhibited higher short-test-effectiveness (STE)[2] values as compared with the Federal Three-Mode for all three pollutants (HC, CO, and NO_x).

b. For the Federal Three-Mode, the idle test modes in drive (automatic transmission) and neutral (both automatic and manual transmissions) were superior to the high and low speed test modes for tracking HC and CO. The high-speed mode was best for NO_x discrimination, although the low-speed mode STE value (0.301) was not significantly different from the high-speed value (0.310) (some vehicles had higher NO_x STE values in the low-speed mode than in the high-speed mode).

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[1] Findings and values noted are based on a single set of ST cut-points selected to yield an error of commission (E_c) rate of 5 percent for each pollutant for the 300-vehicle fleet considered as a whole.

[2] $STE = \frac{\text{\% of vehicles correctly failed by the short test}}{\text{\% FTP failures in same fleet}}$

c. In the case of CO, which was the dominant failure mode on the FTP for the 300-vehicle fleet, the idle-in-drive test mode STE value (0.562) was reasonably close to the Federal Short Cycle STE value (0.690).

d. On a multiple-constituent test basis,[1] the idle-in-drive test mode STE value (0.704) of the Federal Three-Mode is reasonably close to the Federal Short Cycle STE value (0.821).

e. The idle-in-neutral test mode, which would be required for cars with manual transmissions, was lower in STE value than the idle-in-drive test mode: 10 percent lower for HC; 7 percent lower for CO; and 15 percent lower on the multiple-constituent test basis.

f. Using a 5 percent E_c rate to select the short test cut points, a short test rejection ratio (STRR)[2] value of one was not exceeded in any test mode; i.e., the total number of vehicles rejected by the ST as failures (E_c + FF)[3] did not exceed the number of vehicles actually failing the FTP (E_o + FF). By selecting cut-points based on the emission characteristics of the pooled 300-vehicle fleet, then, the auto manufacturers would not have been subjected to a warranty liability (in terms of total number of vehicles rejected) in excess of that properly justified on the basis of the FTP failure rate.

H-2 IMPACT OF CUT-POINT DETERMINATION METHOD

a. When the ST cut-points were based on a 5 percent E_c rate for the total 300-vehicle fleet, which was the basis for the H-1

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[1] A car fails the ST if any one of its HC, CO, or NO_x measurements exceed the cut-points for each pollutant.

[2] $$\text{STRR} = \frac{\text{number of vehicles rejected by the ST}}{\text{number of vehicles rejected by the FTP}}$$

[3] E_c = error of commission
E_o = error of omission
FF = vehicles failed by both the ST and the FTP
PP = vehicles passed by both the ST and the FTP

findings above, higher ST failure rates were observed for the smaller vehicles than for the larger vehicles in terms of CO and NO_x discrimination. This was exemplified by generally higher E_c values (and concomitant STRR values) for:

(1) the 150 CID and less displacement group
(2) the 2500-lb and less weight group
(3) manual-transmission-equipped vehicles
(4) fuel-injected vehicles.

For example, in the case of CO the 150 CID and less group had a 12.5 percent E_c rate while the 260 CID and above group had a 1.8 percent E_c rate.

The small CID, low vehicle weight, and manual transmission factors are all typical attributes of the small-vehicle class. Fuel injection, at present, is also principally used in the small-vehicle class. The observed higher short test failure rate of the smaller vehicles can be interpreted as inequitable to the small vehicle class.

b. Similarly, there was a considerable variation between vehicle manufacturers with regard to E_c rate and STE and STRR values. For example, using the idle-in-drive test mode for a multiple-constituent test: E_c rates varied from 1.6 to 9.3 percent; STE values ranged from 0.500 to 0.800; and STRR values ranged from 0.518 to 0.909.

c. When three sets of ST cut-points were used to minimize engine displacement-related effects, based on a 5 percent E_c rate for each of three CID classes (150 CID and less; 151 to 259 CID; 260 and greater CID), only very minor changes were noted to overall fleet STE values for the individual STs or test modes (as obtained with the single set of ST cut-points based on a 5 percent E_c rate for the fleet). However, there was considerable variation in E_c, STE, and STRR values between manufacturers within each CID class. Also, for a given manufacturer, there were similar variations between CID classes.

d. Even though the overall fleet STE values were essentially unchanged with the three sets of CID-related cut-points, 36 percent more large vehicles (260 CID and greater) were correctly identified as CO failures than with the single set of cut points. Since the mean CO level of this large vehicle class exceeds the FTP CO standard by 14.5 g/mi (compared to the 150 CID and less group with a mean CO level that exceeds the FTP standards by only 1.8 g/mi), the multiple cut-point approach based on CID class represents a greater potential for overall CO reduction.

e. The above findings indicate that:

(1) A single set of cut-points (based on a given E_c rate for the total fleet), while providing reasonable STE and STRR values on an overall fleet basis, results in inequities between vehicle size classes and vehicle manufacturers.

(2) Multiple cut-points based on engine CID class largely resolve the inequities among vehicle size classes; however, large variations between manufacturers in E_c, STE, and STRR values still persist under this scheme.

(3) It may be desirable to select ST cut-points on the basis of CID (or size) and vehicle manufacturer in order to minimize the E_c, STE, and STRR variations noted above. There may be the further consideration of emission control and drive train technology, as discussed in H-3 below.

(4) Since the 5 percent E_c rate resulted in STRR values less than one, the number of correctly failed vehicles in all classes could be increased merely by selecting the ST cut-points to result in an STRR value of one. By this technique, the maximum number of correctly failed vehicles would be obtained under the constraint of not exceeding the number of vehicles that should have been failed based on the observed FTP failure rate.

H-3. EFFECT OF EMISSION CONTROL, FUEL SYSTEM, AND TRANSMISSION TYPE

a. Comparisons were made of the effects of three other sub-groups on the basis of a single set of cut-points for the 300-vehicle fleet (5 percent E_c rate):

1. the use or non-use of catalysts and/or secondary air injection
2. carburetion vs fuel injection
3. manual vs automatic transmissions

b. No significant STE patterns or trends were observed for the catalyst/secondary air sub-group. However, STRR values of one were exceeded by the "without catalyst/with secondary air" category for CO and by the "without either catalyst or secondary air" category for NO_x.

c. Fuel-injected and carbureted vehicles had different and varying STE values; no significant patterns were observed. The fuel-injected vehicles, however, exceeded STRR values of one for both CO and NO_x.

d. Vehicles with manual transmissions had lower HC STE values and higher CO STE values than vehicles with automatic transmissions. With the high-speed test mode, the manual transmission NO_x STE value was 150 percent higher than that of the automatic transmission. NO_x STRR values exceeded one for the manual transmission (high-speed test mode).

e. Thus, the STs examined appear to be applicable to the above control system and vehicle technological variations, with the trends as noted. However, the extent to which these trends would persist or change with other cut-point selection criteria (e.g., cut-points based on CID class, or based on CID class and manufacturer) is not known at this time because of an insufficient test sample size to support the required analyses.

H-4. MULTIPLE-CONSTITUENT VERSUS SINGLE-CONSTITUENT TESTS

a. Single-constituent tests on the Federal Three-Mode require at least two test modes to discriminate all three regulated pollutants (e.g., idle mode for HC and CO, high or low speed mode for NO_x). A multiple-constituent test using only the idle-in-drive test mode produced a higher STE value (0.704) than the next highest single test mode (the idle-in-drive mode for CO discrimination, at 0.562).

H-5. SIMULATION OF 207(b) IMPLEMENTATION

a. The implementation of a 207(b) program was simulated with computer models. The 300-car data set was used to model the fleet emission characteristics and to establish the ST inspection pass-fail levels. Because of uncertainties in the areas of deterioration rates and maintenance effectiveness, sensitivity analyses were performed by using several different maintenance models and by varying many other parameters.

b. With the first inspection occurring when each vehicle is one year old (with an accumulated mileage of 17,500 miles), and with succeeding inspection and maintenance cycles occurring annually, it was determined that the following cumulative program efficiencies[1] would result at the end of 50,000 miles of travel:

HC = 22.1 to 34.6 percent
CO = 24.6 to 42.5 percent
NO_x = 0.33 to 2.00 percent

c. The above ranges of program effectiveness values are the result of specific assumptions made in the modeling process, and principally reflect variations in duration of the period of maintenance effectiveness [2] plus the degree of effectiveness of the maintenance performed at the time of inspection.

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[1] Percent efficiency is the percent reduction in fleet emissions from that value which would have occurred without the 207(b) program, over the mileage interval 17,500 to 50,000 miles.

[2] The period of maintenance effectiveness is the time interval (in months) required for emissions to return to pre-maintenance levels.

1. SUMMARY AND DISCUSSION

1.1 SUMMARY OVERVIEW

1.1.1 Conventional Correlation Analyses

A conventional correlation analysis was performed for the three-city 300-vehicle 1975 model year fleet for both the Federal Short Cycle and the Federal Three-Mode STs. The correlation coefficient is the quantitative measure of relatability between the results of the short test (ST) and the Federal Test Procedure (FTP). The closer the coefficient is to one, the better the relation. No relationship is indicated by a coefficient value of zero. A negative coefficient indicates an inverse relation between the observed test results.

1.1.1.1 Short Test (ST) Comparison

A comparison of the Federal Short Cycle results and the better modes of the Federal Three-Mode ST is shown below in Table 1-1.

Table 1-1. Comparison of ST Correlation Coefficients (Pooled Fleet of 300 Vehicles)

Short Test	ST/FTP Correlation Coefficient		
	HC	CO	NO_x
Federal Short Cycle	0.78	0.89	0.81
Federal Three-Mode	0.58[a]	0.67[a]	0.52[c]
	0.45[b]	0.69[b]	0.48[d]

[a] Idle in drive test mode

[b] Idle in neutral test mode

[c] High speed test mode

[d] Low speed test mode

The Federal Short Cycle exhibited superior FTP tracking characteristics (higher correlation coefficients) as compared to the Federal Three-Mode for all three pollutants (HC, CO and NO_x)*. For the Federal Three-Mode ST, the idle test mode in neutral (both automatic and manual transmissions) and drive (automatic transmission only) was superior to the high and low-speed test modes for tracking HC and CO. The high-speed mode was best for NO_x discrimination, although the low-speed mode coefficient was not significantly different from the high-speed value.

1.1.1.2 Effect of Accumulated Mileage

Seventy of the 300 vehicles had accumulated 4000 miles or less of travel prior to being tested. The only noticeable effect for the Federal Short Cycle is that these 70 vehicles had a higher HC correlation and lower CO correlation than the 230 vehicles with greater than 4000 mileage accumulation. In the case of the Federal Three- Mode, the results for the greater than 4000 mileage group were generally similar to those for the total 300-vehicle fleet. Those vehicles with 4000 miles or less, however, exhibited generally poorer correlation coefficients than the fleet average, except for HC in the idle in drive test mode which was higher than the fleet average. This is in agreement with the HC results noted above for these same low mileage vehicles when tested by the Federal Short Cycle ST.

1.1.1.3 Effect of Engine Displacement

In the case of the Federal Short Cycle, NO_x correlations were largely unaffected by engine cubic inch displacement (CID) class and were similar to the total fleet values. The CO correlations of the 150 CID or less group were significantly lower than the fleet average (and larger engine size groups). In terms of HC discrimination, the 260 CID or more

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*HC = hydrocarbon
CO = carbon monoxide
NO_x = oxides of nitrogen

engine group had a significantly higher correlation coefficient than the fleet average, the 150 CID or less group was slightly less than the fleet average, and the 151 to 259 CID group was significantly lower (0.53) than the fleet average (0.78). A possible explanation for the poorer HC and CO correlation values for the small CID group is that this group incorporated a multiplicity of technologies for HC and CO control (e.g., with and without catalysts, both carburetion and fuel injection, with and without air injection), whereas the large displacement vehicles were principally equipped with carburetors and oxidation catalysts. .

For the Federal Three-Mode ST, similar trends are observed for NO_x in the high-speed mode and for CO in the idle in drive mode. HC correlation coefficients in the idle in drive mode for the two smaller CID groups are higher than the 260 CID and above group, and also higher than the fleet average. Again, the better test modes of the Federal Three-Mode (for a given pollutant) tend to show the same types of trends with engine displacement as the Federal Short Cycle, except for HC.

1.1.1.4 Effect of Inertia Test Weight Group

The Federal Short Cycle results indicate that NO_x correlations are relatively insensitive to inertia weight, whereas the HC and CO correlation coefficients of the 2500 lb and less group (subcompacts) are significantly lower than the heavier weight vehicles. As noted above, the smaller vehicles incorporated varying technologies for HC and CO control, whereas the larger vehicles were principally limited to carburetors and catalysts for HC and CO control.

For the Federal Three-Mode, the NO_x correlation coefficients are similarly relatively insensitive to inertia weight. The discernable trends for HC and CO (in idle in drive and neutral test modes) again indicate lower coefficient values for the smallest test weight group, as was the case for the Federal Short Cycle.

1.1.1.5 Effect of Emission Control System Type

The correlation coefficients of the three-city vehicle fleet were determined as a function of the usage or non-usage of oxidation catalysts and/or secondary air injection for control of HC and CO. In the case of the Federal Short Cycle results, the data indicates generally higher HC and CO correlations with the use of a catalyst (with or without secondary air); however, the 25 vehicles without either a catalyst or secondary air had a CO correlation coefficient (0.86) as high as the 89 vehicles with both a catalyst and secondary air injection (0.86). NO_x correlations are relatively unaffected by the use or non-use of catalysts and/or secondary air injection.

The Federal Three-Mode results are less clear. For example, in the idle in drive mode, the HC correlation coefficients for those vehicles without a catalyst (or secondary air) (0.85 and 0.86) are higher than for those vehicles with a catalyst (and secondary air) (0.46 and 0.62). The twelve vehicles without a catalyst or secondary air had a higher CO correlation coefficient (0.88) than vehicles with a catalyst (and secondary air) (0.77 and 0.67). NO_x correlations (in the high speed and low speed test modes) were relatively little affected by catalyst and secondary air usage, as in the case of the Federal Short Cycle ST.

1.1.1.6 Effect of Carburetion vs Fuel Injection

Thirty vehicles of the 300-vehicle test fleet were equipped with fuel injection. The fuel injected vehicles had significantly poorer Federal Short Cycle correlation coefficients for all three pollutants than the carbureted vehicles. With the Federal Three-Mode ST, this was reversed for NO_x and HC; in the high speed test mode the fuel injected NO_x coefficient (0.63) was higher than the carbureted value (0.53); and in the idle in drive test mode the fuel injected HC coefficient (0.80) was higher than the carbureted value (0.58). When the idle in neutral test mode is considered, the HC comparison is reversed, with the fuel injected coefficient (0.36) lower than the carbureted value (0.46).

1.1.1.7 Effect of Transmission Type

Seventy-one of the 300-vehicle test fleet were equipped with manual transmissions; the remainder were equipped with automatic transmissions. With the Federal Short Cycle ST, the NO_x correlation coefficient was unaffected by transmission type, whereas both HC and CO correlation coefficients were significantly reduced for manual transmission vehicles.

In the case of the Federal Three-Mode ST, the situation is similar for NO_x. For HC and CO, the only comparative basis is the idle in neutral test mode, since the manual transmission prevents the idle in drive test mode. Here the CO correlation coefficients are similar for both transmissions (0.71 and 0.67), and the HC coefficient for the manual transmission (0.33) is considerably lower than the automatic transmission value (0.49).

1.1.1.8 Effect of Manufacturer

On the Federal Short Cycle, General Motors and AMC vehicles had uniformly high (0.9 and above) correlation coefficients for all three pollutants. Ford had the highest HC and CO coefficients (0.94 and 0.96, respectively) but a lower NO_x coefficient (0.77). Chrysler had CO and NO_x coefficients similar to Ford values, but had a lower HC coefficient (0.81). The "others" category (primarily small imported vehicles) had the lowest HC (0.51) and CO (0.65) correlations, with a NO_x value (0.85) slightly higher than Ford and Chrysler values. Again, the multiplicity of technologies used for HC and CO control in the small import class could be responsible for the observed lower correlations when grouped into the single category.

On the Federal Three-Mode ST, the high speed test mode resulted in generally similar NO_x correlation coefficient levels (0.64 to 0.72) for all manufacturers except General Motors, which had a value of 0.42. General Motors, Ford and "others" vehicles had slightly higher NO_x coefficients in the low speed mode than in the high speed mode. In the case of CO in the idle in drive test mode, Ford, General Motors, and AMC relative rankings were similar to that of the Federal Short Cycle, however, Chrysler CO coefficients were lower (0.68) than the other domestic manufacturers (0.73 to 0.84). The "others" category had a very low (0.32) CO coefficient in the idle in drive mode. Conversely, the HC coefficient of the "others" category in the idle in drive mode was the highest (0.82) of all manufacturer groupings. AMC also maintained a high HC coefficient (0.81) in this same test mode. The other three domestic manufacturers had similar, but lower, HC coefficients in the 0.55 to 0.63 range.

1.1.2 Contingency Table Analysis

The contingency table analysis technique was used to establish the ST pass-fail levels for each pollutant. The contingency table is defined in Table 1-2, along with its associated parameters. A pictorial demonstration of its application to a given data set is shown in Figure 1-1. It can be seen that, for a given data set, part of the analysis is concerned with the criteria used to select the ST cut-points. In this regard, the bounded errors of commission method was used extensively to establish trends for the variations in E_c, E_o, FF, and PP (see definitions in Table 1-2). In this method, the ST cut-points are selected to minimize E_o while holding the E_c below a specified level. It thus permits a direct answer to the question, "For a given permissible level of E_c, what level of E_o is associated with the ST, and with what impact on air quality (inferred from number of FF and E_o vehicles)?" This method is illustrated in Figure 1-2. The policy decision is the maximum allowable E_c.

With regard to procedural technique, a bivariate normal or log-normal distribution model was fitted to a particular data set by incorporating the correlation coefficient, mean values, and standard deviations of the data set. The ST cut-points were then determined by using the model for the predicted population of the 300-vehicle fleet.

Table 1-2. Contingency Table

		True = FTP		
		Pass	Fail	Total
Predicted = Short Test	Pass	a	b	a + b
	Fail	c	d	c + d
	Total	a + c	b + d	n = a + b + c + d

a = number of correctly passed vehicles (PP)

b = number of errors of omission (E_o)

c = number of errors of commission (E_c)

d = number of correctly failed vehicles (FF)

Sensitivity = a/(a + c)
Specificity = b/(b + d)
False positive error = b/(a + b)
False negative error = c/(c + d)

$$\text{Correlation index} = \frac{ad - bc}{[(a + b)(a + c)(b + d)(c + d)]^{1/2}}$$

Also determined in the contingency table analysis were the short test "effectiveness" (STE) and the short test "rejection ratio" (STRR). ST effectiveness is defined as:

$$\text{ST effectiveness} = \text{STE} = \frac{\%\ \text{FF for the short test}}{\%\ \text{FTP failures in same population}} \qquad (1\text{-}1)$$

$$= \frac{\%\ \text{FF}}{\%\ \text{FF} + \%\ E_o}$$

Thus, on this basis, the ST is always less effective than the FTP, in proportion to the percent of errors of omission (E_o) associated with a given ST,

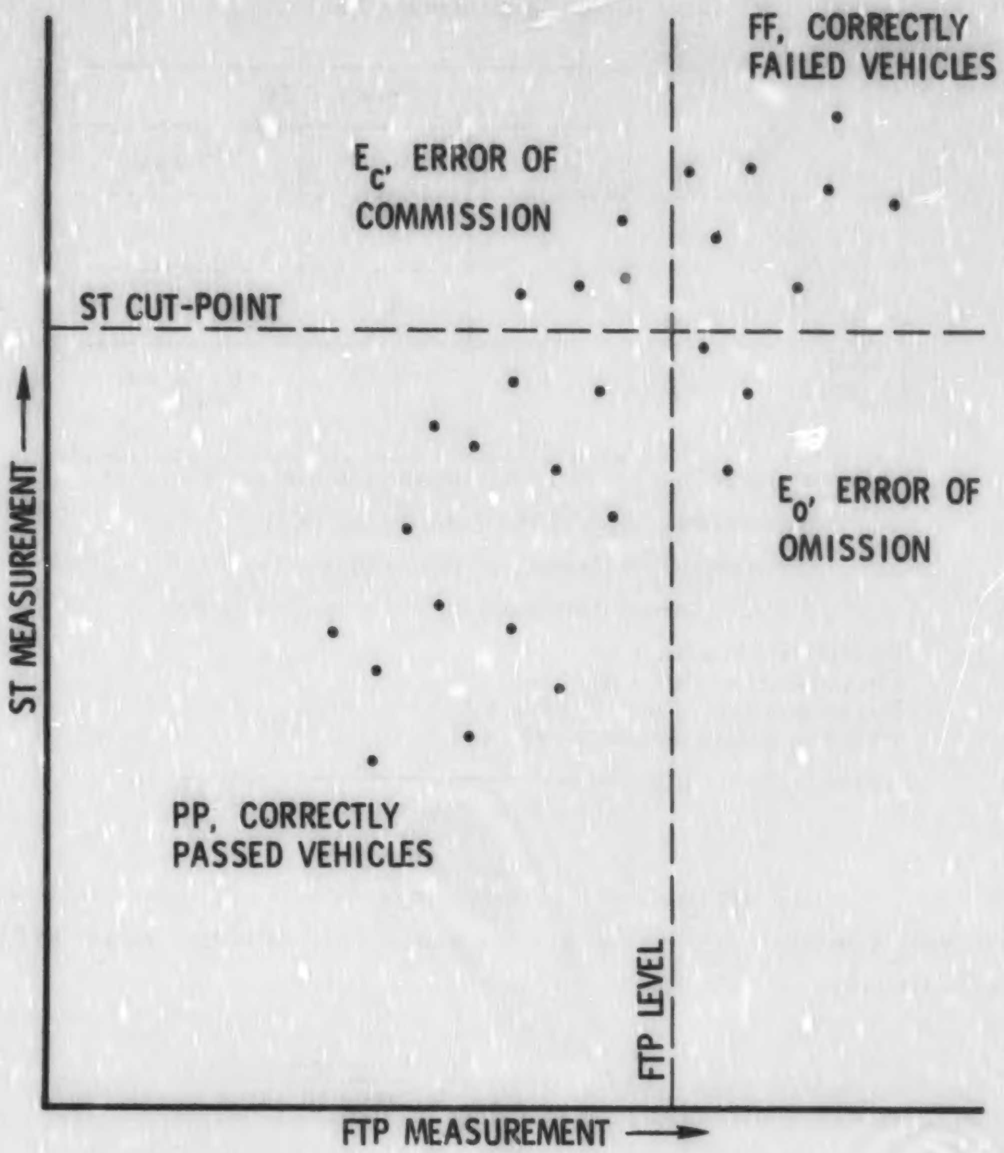
FF, CORRECTLY
FAILED VEHICLES
E_C, ERROR OF
COMMISSION
ST CUT-POINT
E_O, ERROR OF
OMISSION
PP, CORRECTLY
PASSED VEHICLES
ST MEASUREMENT →
FTP LEVEL
FTP MEASUREMENT →

Figure 1-1. Contingency Table Representation

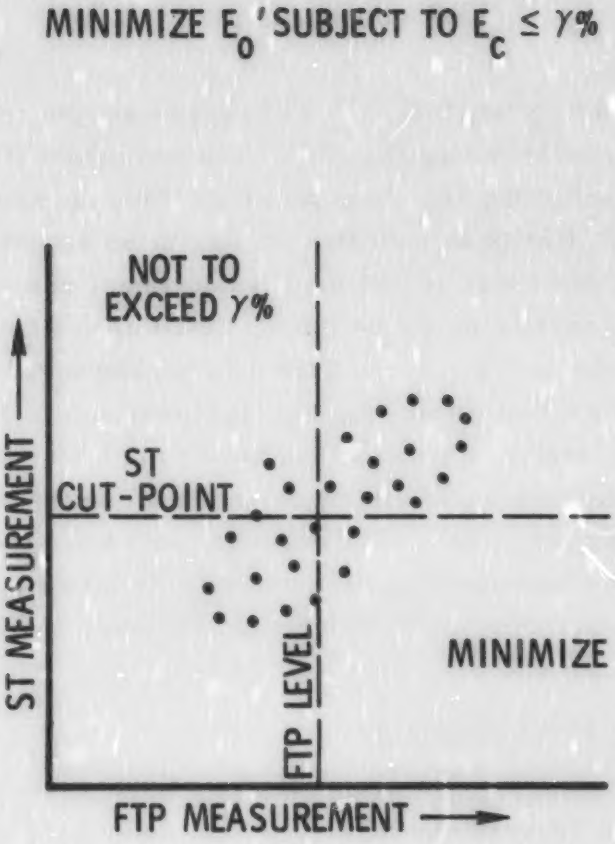
MINIMIZE E_O' SUBJECT TO $E_C \leq \gamma\%$
NOT TO EXCEED γ%
ST CUT-POINT
FTP LEVEL
MINIMIZE
ST MEASUREMENT →
FTP MEASUREMENT →

Figure 1-2. Bounded Errors of Commission Method

and the STE value is a relative measure of the impact on air quality from ST implementation.

The short test rejection ratio is defined as:

$$\text{STRR} = \frac{\% E_c + \% FF}{\% E_o + \% FF} \qquad (1\text{-}2)$$

The denominator of this ratio ($\% E_o + \% FF$) represents the percent of the vehicle population actually failing the FTP. The numerator ($\% E_c + \% FF$) represents the percent of the vehicle population failing the short test. Thus, the resultant ratio (STRR) is an indication to flag those situations where the implementation of a short test or test mode could result in a greater number of vehicles being failed than should be failed, based upon FTP standards. Whereas the STE value is a measure of the relative impact of the use of the ST on air quality, the STRR value, which includes consideration of those E_c vehicles incorrectly identified by the ST as failing the FTP, can be considered a relative measure of the "fairness" of the ST to the vehicle manufacturer or vehicle size or class. For example, only when the STRR value exceeds one would the manufacturer be required to implement warranty procedures on a greater number of vehicles than he should have, based upon the observed FTP failure rate.

1.1.2.1 Short Test Comparison

A comparison of the Federal Short Cycle results and the better modes of the Federal Three-Mode ST is shown in Table 1-3.

As was the case with conventional correlation analysis (Section 1.1.1.1), the Federal Short Cycle exhibited superior STE values as compared to the Federal Three-Mode for all three pollutants (HC, CO and NO_x). However, in the case of CO, which was the dominant failure mode on the FTP for the 300-vehicle fleet, the idle test mode STE value (0.562) was reasonably close to the Federal Short Cycle value (0.690). Further, when considering the idle mode in drive as a multiple constituent test (i.e., a car fails the ST of any one of its HC, CO, or NO_x measurements exceed

Table 1-3. Comparison of ST Contingency Table Values for STE and STRR; All Three Cities (E_c Set at 5 Percent for Pooled Fleet of 300 Vehicles)

Short Test	Parameter							
	HC		CO		NO_x		Multiple Constituents[(a)]	
	STE	STRR	STE	STRR	STE	STRR	STE	STRR
Federal Short Cycle	0.589	0.748	0.690	0.783	0.604	0.840	0.821	0.928
Federal Three-Mode								
High Speed Mode	-	-	-	-	0.310	0.547	-	-
Low Speed Mode	-	-	-	-	0.301	0.538	-	-
Idle in Drive	0.375	0.533	0.562	0.652	-	-	0.704	0.801
Idle in Neutral	0.338	0.495	0.524	0.614	-	-	0.597	0.669
Combination of Best Modes (b)	-	-	-	-	-	-	0.663	0.729

(a) Car fails the ST if any of its HC, CO, or NO_x measurements exceed the cut-points for each pollutant.

(b) Combination of best individual test modes (idle in drive for HC and CO, high speed for NO_x).

the cut-points for each pollutant), then the idle mode STE value (0.704) is reasonably close to the Federal Short Cycle value (0.821). The idle in neutral test mode, although not quite as effective as the idle in drive mode, would be required for those cars with manual transmissions.

Table 1-4 shows the variation of STE values achieved in the three cities in which the vehicles were tested. The most notable difference is the Federal Three-Mode NO_x STE value in Phoenix, which is approximately twice that of the other two cities. The humidity in Phoenix is considerably lower and more consistent in level than in the other two cities. The NO_x correction factor for humidity was applied to the Federal Short Cycle and the FTP test results, but was not applied to the Federal Three-Mode results. This accounts for the relative uniformity of correlation existing for the Federal Short Cycle in all three cities and the non-uniformity of the Federal Three-Mode results. If the NO_x humidity correction factor had been applied, the Chicago and Houston results would probably be similar to the results obtained in Phoenix.

With regard to short test rejection ratio, the STE values of Table 1-3 were achieved without exceeding an STRR value of one in any case, i.e., the total number of vehicles rejected by the ST as failures (E_c + FF) did not exceed the number of vehicles actually failing the FTP (E_o + FF). By selecting cut-points based on the emission characteristics of the pooled 300-vehicle fleet, then, the auto manufacturers would not have been subjected to a warranty liability (in terms of total number of vehicles rejected) in excess of that properly justified on the basis of FTP failure rate.

The above findings are restricted solely to the case of overall fleet averages. Because the makeup of the 300-vehicle test fleet represented a cross-section of the 1975 model year in-use population, the test fleet included the many variables of manufacturer, vehicle size (inertia test weight), engine size (displacement), emission control system type, transmission type, and fuel system type. As would be expected, individual findings for each of these sub-groups of the total fleet varied somewhat from that for the overall

Table 1-4. Comparison of STE Values for Three Cities

	Short Test Effectiveness (STE)								
	Chicago			Houston			Phoenix		
Short Test	HC	CO	NO_x	HC	CO	NO_x	HC	CO	NO_x
Federal Short Cycle	0.554	0.664	0.618	0.691	0.731	0.562	0.530	0.676	0.645
Federal Three-Mode									
High Speed	-	-	0.204	-	-	0.249	-	-	0.535
Low Speed	-	-	0.177	-	-	0.291	-	-	0.471
Idle in Drive	0.405	0.539	-	0.360	0.584	-	0.349	0.551	-
Idle in Neutral	0.352	0.509	-	0.348	0.536	-	0.296	0.517	-

fleet. A summary of the more significant variations is presented in the following sections. They are discussed in depth in Sections 1.3.5 through 1.3.11.

The reader is reminded that the following remarks pertain to the 300 vehicles being analyzed as a single group and using a 5 percent E_c rate to select the cut-points.

1.1.2.2 Effect of Engine Displacement

With the Federal Short Cycle, the most significant effect of engine displacement was displayed by the 150 CID and less group. It has a CO STE value (0.773) higher than the fleet average (0.690) and a NO_x STE value (0.530) below the fleet average (0.604). The high CO STE value was accompanied by a CO STRR value of 1.051.

On the Federal Three-Mode ST (idle in drive mode) the same higher CO STE trend of the 150 CID and less group was also evident; however, the NO_x STE value (0.578 high speed mode) was appreciably higher than the fleet average value (0.310) and was accompanied by an NO_x STRR value of 1.219, that is, approximately 22 percent more vehicles failed the ST than failed the FTP.

1.1.2.3 Effect of Inertia Test Weight Group

The most noticeable effects of inertia test weight were associated with the 2500 lb and less weight group. On the Federal Short Cycle, this group had a higher than fleet average CO STE value and had markedly lower than fleet average HC and NO_x STE values. It had an STRR value of 1.064 in the case of CO. On a multiple constituent test basis this group also exceeded an STRR value of one.

On the Federal Three-Mode ST, these same trends for the 2500 lb and less weight group were evident except for NO_x. Using the high speed test mode, the NO_x STE value was the highest of the four weight groups, accompanied by a very high STRR value of 3.0, which was due to a very high (13.2 percent) E_c rate.

1.1.2.4 Effect of Emission Control System Type

With the Federal Short Cycle ST, there appear to be no readily observed STE trends attendant to the use or non-use of catalysts and/or secondary air injection. However, STRR values in excess of one were associated with those vehicles (1) without a catalyst but with secondary air in the case of CO, (2) with a catalyst but without secondary air in the case of NO_x, and (3) without either a catalyst or secondary air in the case of multiple constituents.

On the Federal Three-Mode, again no significant STE patterns or trends were observed. Those vehicles with both a catalyst and secondary air injection did have lower STE values for all three pollutants and on a multiple constituent test basis. In the case of rejection ratio, an STRR value of one was exceeded by the "without catalyst/with secondary air" group for CO (idle in neutral test mode) and by the "without either catalyst or secondary air" group for NO_x (high speed test mode).

1.1.2.5 Effect of Carburetion vs Fuel Injection

With the Federal Short Cycle ST, the fuel-injected vehicles had STE values 20 percent lower than carbureted vehicles for HC, 30 percent higher for CO, and 70 percent lower for NO_x. In the case of both CO and multiple constituents, the fuel injected vehicles had STRR values in excess of one.

On the Federal Three-Mode ST, the above HC and NO_x trends were reversed. The HC STE value of the fuel-injected vehicles was 8 percent higher than that of the carbureted vehicles and the NO_x STE value was 42 percent higher (high speed test mode). The fuel injected vehicles exceeded an STRR value of one for both CO (1.082) and NO_x (1.480).

1.1.2.6 Effect of Transmission Type

With the Federal Short Cycle ST, those vehicles with manual transmissions, compared to those with automatic transmissions, had STE values which were 30 percent lower for HC, 10 percent higher for CO, and

45 percent lower for NO_x. They also exceeded an STRR value of one for CO (1.032).

On the Federal Three-Mode ST, the same HC and CO trends were observed as noted above. However, the NO_x trend was reversed, with the manual transmission STE value (high speed test mode) 150 percent higher than that of the automatic transmission. For NO_x the manual transmission had an STRR value of 1.538.

1.1.2.7 Effect of Manufacturer

With the Federal Short Cycle ST, the most notable effect was the very high NO_x STE value (0.957) recorded by AMC. This was accompanied by a 14.5 percent E_c rate and an STRR value of 2.463. The "others" category (principally small imports) had an STRR value of 1.121 for CO. Both AMC and the "others" exceeded an STRR value of one on a multiple constituents test basis.

On the Federal Three-Mode, the above effects were not noted. Chrysler had the highest CO STE value (0.898, idle in drive) accompanied by an STRR value of 1.016. In the case of NO_x, the "others" category had the highest STE value in the high speed mode (0.467), whereas Chrysler had an STRR value of 2.129 and the highest STE value (0.755) in the low speed test mode.

1.1.2.8 Effect of Cut-Point Determination Method

The foregoing analysis results indicated that, when the ST cut-points were based on a 5 percent E_c rate for the total 300-vehicle fleet, there were possible inequities in terms of CO and NO_x discrimination for the smaller vehicles. This was exemplified by the higher E_c and concomitant STRR values for the 150 CID and less displacement group, the 2500 lb and less weight group, the fuel-injected vehicles, and the manual-transmission-equipped vehicles. The small CID, low vehicle weight, and manual transmission factors are all typical attributes of the small vehicle class. Fuel injection, at its present degree of usage, is also principally used in the small vehicle class.

Therefore an additional contingency table analysis was made wherein the ST cut-points were determined for each CID class, based on a 5 percent E_c rate for that CID class alone, not the pooled 300 vehicle fleet as in all previously discussed results. The results of this second analysis is compared with the first contingency table analysis in Table 1-5. As can be seen, selecting a 5 percent E_c rate for each CID group resulted in very minor changes to overall STE and STRR values for the individual STs or modes. In addition, all STE values were improved, except for (1) the multiple constituent test basis on the Federal Three-Mode and (2) NO_x on the Federal Short Cycle and low speed test mode of the Federal Three-Mode.

These results indicate that the more equitable CID class cut-point determination approach can produce the same benefit in air quality (as indicated by STE value) while reducing the probability of excessive failures of small vehicles by ST implementation. Another approach, not examined in the present study, would be to select cut-points on the basis of a 5 percent E_c rate for each vehicle manufacturer within each CID class.

1.1.3 Simulation of 207(b) Implementation

A computer program was developed to simulate the implementation of a 207(b) program on a specific fleet of vehicles, the "controlled fleet", and to compare the emission results to an uncontrolled fleet, originally identical to the controlled fleet, which deteriorates without the influence of a mandatory 207(b) program. The comparison was made over a 50,000-mile period for each fleet, and the effectiveness of the 207(b) program was assessed annually.

The two simulated fleets were each divided into three mutually exclusive groups based upon engine displacement: 150 CID and less; 151 to 259 CID; and 260 CID and greater. Existing 300-car data was used to establish a distribution model for the emission values of the three regulated pollutants at the mean mileage for each displacement group. This distribution model was then used to stochastically generate the two identical fleets of vehicles with statistical attributes similar to the 300-car data set.

Table 1-5. Comparison of Cut-Point Determination Methods; 5 Percent E_c Fleet Average vs 5 Percent E_c for Each of Three CID Groups

		Short Test Effectiveness (STE)	
Short Test	**Pollutant**	**5% E_c Fleet Average**	**5% E_c for Each of Three CID Groups[a]**
Federal Short Cycle	HC	0.589	0.592
	CO	0.690	0.711
	NO_x	0.604	0.573
	Multiple Constituents[b]	0.821	0.847
Federal Three-Mode	HC		
	Idle in Drive	0.375	0.383
	Idle in Neutral	0.338	0.339
	CO		
	Idle in Drive	0.562	0.605
	Idle in Neutral	0.524	0.557
	NO_x		
	High Speed	0.310	0.341
	Low Speed	0.301	0.291
	Multiple Constituents[b]		
	Idle in Drive	0.704	0.653
	Idle in Neutral	0.597	0.592
	Best Combination	0.663	0.648

[a] 150 CID and less
151 to 259 CID
260 CID and greater

[b] Car fails if any of HC, CO, or NO_x measurements exceed cut-points for each pollutant

The existing 300-car data set was also used to establish the ST inspection pass-fail levels. Two methodologies in selecting the levels were examined. The first method, designated the "207(b) approach", established pass-fail levels for each engine displacement group at a 5 percent error of commission rate for each pollutant. The second method, designated the "I/M approach", established, for each pollutant, a single pass-fail level which applied to all groups. The I/M (inspection maintenance) pass-fail levels were determined using a 33 percent total failure rate with a three-constituent test.

Because of uncertainties in the areas of deterioration rates and maintenance effectiveness, a limited sensitivity analysis was performed by using several different maintenance models and by varying many of the program input parameters. This provided visibility into the variability of the results and identified the most sensitive components of the analysis program.

A maintenance policy was selected for each vehicle individually. If the vehicle was classified by the ST as an E_c or FF vehicle, the FTP emission rates were adjusted to reflect the effect of corrective maintenance. If the vehicle was classified as a PP or E_o vehicle, the FTP emission rates were left undisturbed. Three methods of adjusting the FTP values were investigated, as discussed below.

a. Version 1: Proportionally Coupled with Lower Bounds For HC and CO, a pollutant passing the FTP is reduced by the same proportion as a pollutant failing the FTP. The lower limit of any reduction, beyond the FTP standard, is one-half the FTP standard. NO_x is unaffected by HC and CO maintenance.

b. Version 2: Independent Maintenance to FTP Standard Each pollutant is adjusted independently of the values of the other pollutants. Failing pollutants are adjusted to the respective FTP standard.

c. Version 3: Independent Maintenance to Equivalent ST Standard. Each pollutant is adjusted independently of the values of the other pollutants. Failing pollutants are adjusted to an FTP value that corresponds to the ST cut-point.

The general effects of age and wear were simulated by deteriorating the emission rates from their value at the last inspection and maintenance point to the next I/M point. Deterioration effects on the uncontrolled fleet were based upon linear models with mileage accumulation. The vehicles were classified into two groups:

a. Vehicles passing the FTP
b. Vehicles failing the FTP

Certification deterioration factors were applied to vehicles in group a, and EFP factors were applied to vehicles in group b. The values used are shown in Table 1-6.

Table 1-6. Average Deterioration Rates Used in 207(b) Effectiveness Simulation

Data Source	Rate of Deterioration in Grams/Mile per 1000 Miles		
	HC	CO	NO_x
Certification Values	0.014	0.084	0.0
EFP Values	0.072	0.800	0.0

Deterioration effects on the controlled fleet were based upon piecewise linear models with mileage accumulation. The vehicles were classified into four groups (E_c, E_o, PP, and FF vehicles) and the following deterioration rates were applied.

a. PP Vehicles: Certification rates as shown in Table 1-6
b. E_o Vehicles: EFP rates as shown in Table 1-6
c. E_c Vehicles: Certification rates shown in Table 1-6. Deterioration occurs after the maintenance adjustments.

d. **FF Vehicles**: A maintenance effectiveness period is specified as an input to the simulation program. This period is the number of months (less than or equal to 12) required for the emissions to return to their value just prior to maintenance. After this period, if less than 12 months, the emissions are deteriorated according to the EFP rates as shown in Table 1-6. This situation is displayed in Figure 1-3.

Program effectiveness was based upon total mass of pollutants emitted since the inception of the program, reported annually. For each pollutant, the total grams emitted for each vehicle were calculated for the average mileage accumulations shown in Table 1-7. The total mass for each fleet is calculated by summing over each vehicle within the respective fleets. The effectiveness is then expressible as a percent change relative to the uncontrolled fleet.

1.1.3.1 Simulation Results

Table 1-8 summarizes the simulation results for the 207(b) approach for the three-maintenance versions examined, which have a 12-month maintenance effectiveness period. Maintenance version 3 produced the most conservative estimates of program efficiency, whereas version tended to be the most optimistic. However, the differences between the maintenance versions were quite small and rarely exceeded 10 percent.

Of greater importance is the assumption as to the maintenance period of effectiveness. This is illustrated in Table 1-9 for the 207(b) approach with maintenance version 3. If the emissions of the maintained vehicles returned to pre-maintenance levels in 6 months instead of 12 months, for example, then the effectiveness of the program at the end of the 50,000 miles is substantially reduced (from 32.9 percent to 22.1 percent for HC; from 38.3 percent to 24.6 percent for CO). This result merely quantifies the intuitive knowledge that "the quicker the erosion of maintenance effects, the less the overall impact of maintenance." The differences between

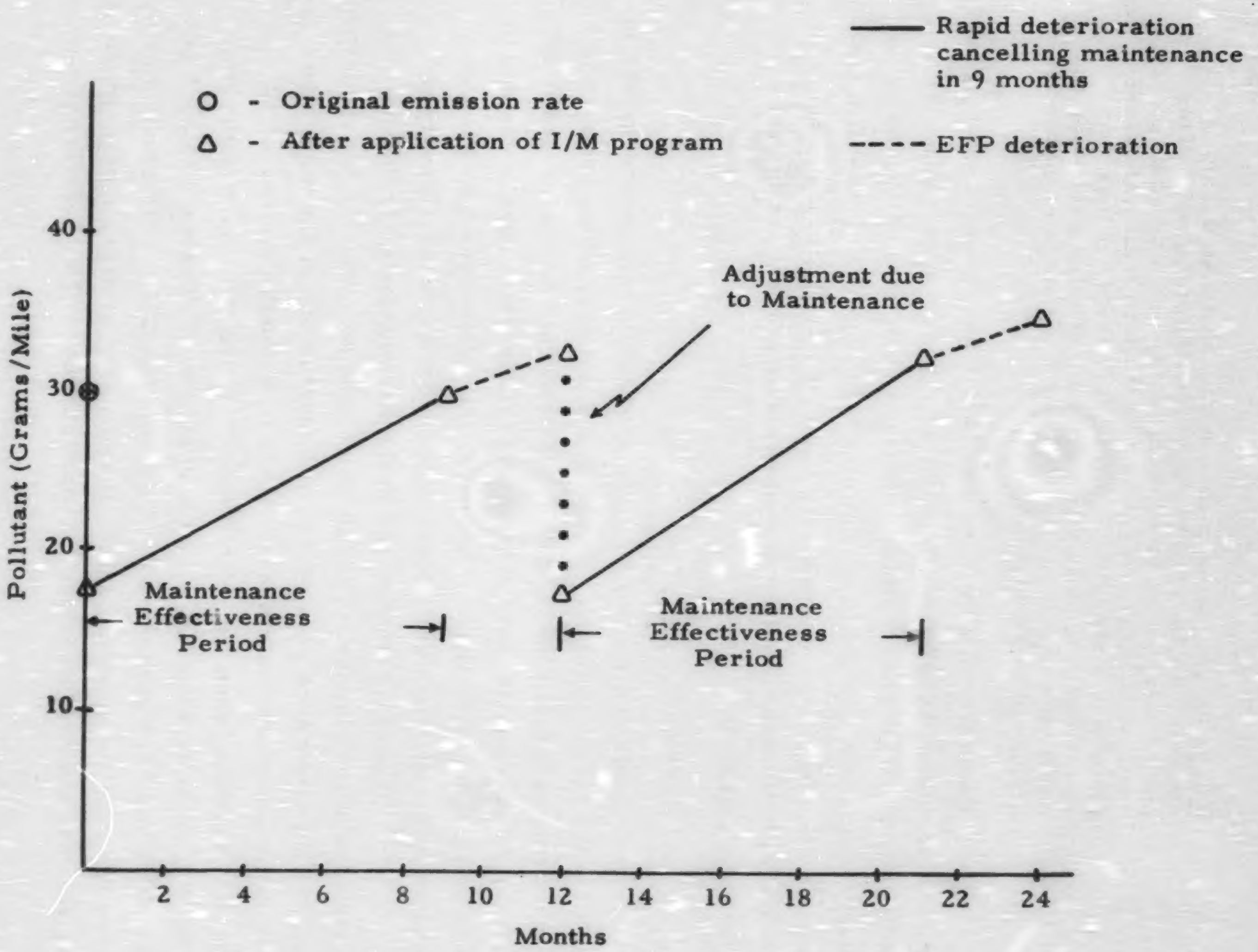

Figure 1-3. Piece-wise Linear Deterioration for FF Vehicles Shown Over Two-Year Period

Table 1-7. Annual Mileage Accumulations Used in 207(b) Effectiveness Simulation

Age of Vehicles In Years	Number of Years In Program	Accumulated Average Mileage[a]	
		Annual	Cumulative
1	0	17,500	17,500
2	1	16,100	33,600
3	2	13,200	46,800
4[b]	3[b]	3,200	50,000

[a] Nationwide Personal Transportation Study; Annual Miles of Automobile Travel, Report No. 2, April 1972, U.S. Department of Transportation

[b] Not a full year - simulation stops at 50,000 miles.

Table 1-8. Variation of 207(b) Program[a] Effectiveness with Various Maintenance Assumptions

Maintenance Assumptions [b]	Emission Values Adjusted to:		Number of Years Since First Inspection	Estimated Program Efficiency in Percent (Cumulative)[c]		
	FTP Standards	Equivalent ST Standards		HC	CO	NO_x
VERSION NO. 1: HC and CO adjustments coupled,[e] NO_x adjustment independent	X		1	22.7	32.4	2.05
			2	31.6	39.0	1.81
			3[d]	34.6	42.5	2.00
VERSION NO. 2: HC, CO and NO_x adjusted independently	X		1	22.7	29.7	2.05
			2	31.6	35.9	1.81
			3[d]	34.6	39.1	2.00
VERSION NO. 3: HC, CO and NO_x adjusted independently		X	1	21.1	29.0	1.78
			2	30.0	35.2	1.53
			3[d]	32.9	38.3	1.70

[a] Pass-fail ST levels set for 5 percent E_c rate for each pollutant for each of three engine CID groups (150 CID and less; 151 to 259 CID; 260 CID and greater).

[b] All three versions shown have 12-month maintenance period effectiveness; i.e., emissions return to pre-maintenance levels in 12 months.

[c] Percent efficiency is the percent reduction in fleet emissions from that value which would have occurred without the 207(b) program, over the time period shown.

[d] Not a full year. Program ended at 50,000 miles.

[e] When either HC or CO is adjusted, the other is adjusted with same percentage reduction; neither HC nor CO permitted to be less than one-half their respective FTP standard.

Table 1-9. 207(b) Program Efficiencies with Maintenance Version 3

Maintenance Period of Effectiveness	Number of Years Since The 1st Inspection	Estimated Program Efficiencies in Percent		
		Cumulative		
		HC	CO	NO_x
12	1	21.1	29.0	1.78
	2	30.0	35.2	1.53
	3[a]	32.9	38.3	1.70
9	1	18.4	23.6	1.05
	2	25.4	28.9	0.82
	3[a]	28.5	32.3	1.05
6	1	13.8	17.0	0.32
	2	18.9	20.8	0.08
	3[a]	22.1	24.6	0.33

[a] Not a full year. Program ended at 50,000 miles.

the 12-month and 6-month periods of maintenance effectiveness were typically about 50 percent for HC, 70 percent for CO, and 500 percent for NO_x.

Table 1-10 summarizes the simulation results for the I/M approach for the same three maintenance versions and the 12-month maintenance period assumed for the 207(b) approach of Table 1-8. The I/M approach exhibits the same general behavior as the 207(b) approach, but shows appreciably lower values of program effectiveness. This is shown more clearly in a direct comparison of the two approaches in Table 1-11. These lower effectiveness values are principally a reflection of the method of selecting the ST cut-points in these two examples and are not intrinsic to 207(b) or I/M, per se.

In the case of I/M, a 33.3 percent total failure rate was selected, which resulted in a 2 percent E_c rate for each pollutant, based on the total vehicle fleet. In the case of 207(b), a 5 percent E_c rate for three engine size groups was selected that resulted in a total failure rate of 42.4 percent. This difference in total failures and in E_c rates is the principal reason for the difference in effectiveness values between the two approaches examined. If they were compared at the same E_c rate, it is unclear as to which approach would be more effective.

In either case, for fixed maintenance effectiveness period and a fixed maintenance version, the efficiency of the program increases as the duration of the program increases. Hence, the earlier the program can be instituted, the greater the resulting benefit on air quality and the higher will be the program efficiency at 50,000 miles.

It is emphasized that the program effectiveness values shown in Tables 1-8 through 1-11 are the result of the specific assumptions made, and are highly dependent upon the duration of the maintenance effectiveness period as well as the estimated effectiveness of the maintenance performed at the time of inspection. One limitation inherent in the three maintenance versions examined herein is that an E_c vehicle is always either an FF or E_o vehicle the following year. This results because of the deterministic approach employed; this limitation can perhaps be eliminated in future analyses through the use of stochastic maintenance models.

Table 1-10. Variation of I/M Programs[a] Effectiveness with Various Maintenance Assumptions

Maintenance Assumptions[b]	Emission Values Adjusted to:		Number of Years Since First Inspection	Estimated Program Efficiency in Percent (Cumulative)[c]		
	FTP Standards	Equivalent ST Standards		HC	CO	NO_x
VERSION NO. 1: HC and CO adjustments coupled;[e] NO_x adjustment independent	X		1	16.4	24.3	1.59
			2	24.0	30.3	1.58
			3[d]	27.0	33.8	1.78
VERSION NO. 2: HC, CO and NO_x adjusted independently	X		1	16.4	22.2	1.59
			2	24.0	27.7	1.58
			3[d]	27.0	30.8	1.78
VERSION NO. 3: HC, CO and NO_x adjusted independently		X	1	14.3	18.4	1.04
			2	21.2	23.6	0.99
			3[d]	23.7	26.1	1.13

[a] A single pass-fail ST level for each pollutant for all cars in fleet, regardless of engine CID. ST levels set to provide a 33 percent total failure rate with a three-constituent test.

[b] All three versions shown have 12-month maintenance period effectiveness; i.e., emissions return to pre-maintenance levels in 12 months.

[c] Percent efficiency is the percent reduction in fleet emissions from that value which would have occurred without the I/M program, over the time period shown.

[d] Not a full year. Program ended at 50,000 miles.

[e] When either HC or CO is adjusted, the other is adjusted with same percentage reduction. Neither HC nor CO permitted to be less than one-half their respective FTP standard.

Table 1-11. Comparison of Effectiveness of 207(b) and I/M Program Approaches; Maintenance Version 3; 12-Month Maintenance Period Effectiveness

Program Type	Number of Years Since First Inspection	Estimated Program Efficiency in Percent (Cumulative)[(a)]		
		HC	CO	NO_x
207(b) Program[(b)]	1	21.1	29.0	1.78
	2	30.0	35.2	1.53
	3[(d)]	32.9	38.3	1.70
I/M Program[(c)]	1	14.3	18.4	1.04
	2	21.2	23.6	0.99
	3[(d)]	23.7	26.1	1.13

(a) Percent efficiency is the percent reduction in fleet emissions from that value which would have occurred without the 207(b) program, over the time period shown.

(b) Pass-fail ST levels set for 5 percent E_c rate for each pollutant for each of three engine CID groups (150 CID and less; 151 to 259 CID; 260 CID and greater). This resulted in a total failure rate of 42 percent.

(c) A single pass-fail level for each pollutant for all cars in fleet, regardless of engine CID. ST levels set to provide a 33 percent total failure rate with a three-constituent test.

(d) Not a full year. Program ended at 50, 000 miles.

1.2 CONVENTIONAL CORRELATION ANALYSIS DISCUSSION

1.2.1 Results for All Three Cities Combined

A summary of the ST/FTP correlation coefficients obtained for the pooled fleets of all three cities (300 vehicles) is given in Table 1-12.

1.2.1.1 Short Test Comparison

The Federal Short Cycle exhibited superior FTP tracking characteristics (higher correlation coefficients) as compared to the Federal Three-Mode for all three pollutants (HC, CO and NO_x).

For the Federal Three-Mode ST, the idle test mode in neutral (both automatic and manual transmissions) and drive (automatic transmission only) was superior to the high-and-low-speed test modes for tracking HC and CO. The high-speed mode was best for NO_x discrimination, although the low-speed mode coefficient (0.48) was not significantly different than the high-speed value (0.52).

1.2.1.2 Effect of Accumulated Mileage

Seventy of the 300 vehicles had accumulated 4000 miles or less of travel prior to being tested. As shown in Table 1-13, the only noticeable effect for the Federal Short Cycle is that these 70 vehicles had a higher HC correlation and lower CO correlation than the 230 vehicles with greater than 4000 mileage accumulation. In the case of the Federal Three-Mode, the results for the greater than 4000 mileage group were generally similar to those for the total 300-vehicle fleet (Table 1-12). Those vehicles with 4000 miles or less, however, exhibited generally poorer correlation coefficients than the fleet average, except for HC in the idle in drive test mode which was higher than the fleet average. This is in agreement with the HC results noted above for these same low mileage vehicles when tested by the Federal Short Cycle ST.

Table 1-12. Correlation Coefficient Summary – All Three Cities

Short Test	Test Mode	No. of Vehicles	ST/FTP[a] Correlation Coefficients[b]		
			HC	CO	NO_x
Federal Short Cycle		300	0.78	0.89	0.81
Federal Three-Mode	High speed	300	0.31	0.33	0.52
	Low speed	300	0.47	0.46	0.48
	Idle in neutral	300	0.45	0.69	0.11*
	Idle in drive	229	0.58	0.67	0.12*

[a] ST/FTP = short test/federal emission certification test procedure

[b] Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

Table 1-13. Correlation Coefficient Summary by Accumulated Mileage — All Three Cities

Short Test	Mileage Group(a)	Test Mode	No. of Vehicles	ST/FTP(b) Correlation Coefficients(c)		
				HC	CO	NO_x
Federal Short Cycle	4000 or less		70	0.91	0.80	0.79
	Greater than 4000		230	0.76	0.90	0.82
Federal Three-Mode	4000 or less	High speed	70	0.13*	0.16*	0.36
		Low speed	70	0.29	0.31	0.40
		Idle in drive	48	0.80	0.61	-0.08*
		Idle in neutral	70	0.37	0.55	0.02*
	Greater than 4000	High speed	230	0.33	0.37	0.54
		Low speed	230	0.52	0.54	0.49
		Idle in drive	181	0.54	0.67	0.23
		Idle in neutral	230	0.45	0.71	0.14*

(a) Number of accumulated miles on vehicles tested

(b) ST/FTP = short test/federal emission certification test procedure

(c) Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

1.2.1.3 Effect of Engine Displacement

Table 1-14 displays the three-city correlation coefficients as a function of engine cubic inch displacement (CID) class. In the case of the Federal Short Cycle, NO_x correlations were largely unaffected by CID class and were similar to the total fleet values of Table 1-12. The CO correlations of the two larger CID groups were similar to the fleet average, whereas the 150 CID or less group had a significantly lower CO correlation than the fleet average (and larger engine size groups). In terms of HC discrimination, the 260 CID or more engine group had a significantly higher correlation coefficient than the fleet average; the 150 CID or less group was slightly less than the fleet average; and the 151 to 259 CID group was significantly lower (0.53) than the fleet average (0.78).

For the Federal Three-Mode ST, similar trends are observed for NO_x in the high-speed mode and for CO in the idle in drive mode. HC correlation coefficients in the idle in drive mode for the two smaller CID groups are higher than the 260 CID and above group, and also higher than the fleet average of Table 1-12.

Again, the better test modes of the Federal Three-Mode (for a given pollutant) tend to show the same types of trends with engine displacement as the Federal Short Cycle, except for HC.

1.2.1.4 Effect of Inertia Test Weight Group

The correlation coefficients of the 300 vehicles (all three cities) divided into four inertia test weight groups are shown in Table 1-15. The Federal Short Cycle results indicate that NO_x correlations are relatively insensitive to inertia weight, whereas the HC and CO correlation coefficients of the 2500 lb and less group (subcompacts) are significantly lower than the heavier weight vehicles.

For the Federal Three-Mode, the NO_x correlation coefficients are similarly relatively insensitive to inertia weight. The discernible trends for HC and CO (in idle in drive and neutral test modes) again indicate lower coefficient values for the smallest test weight group, as was the case for the Federal Short Cycle.

Table 1-14. Correlation Coefficient Summary by Engine Displacement — All Three Cities

Short Test	CID(a) Group	Test Mode	No. of Vehicles	ST/FTP(b) Correlation Coefficients(c)		
				HC	CO	NO_x
Federal Short Cycle	150 or Less		95	0.71	0.63	0.82
	151 to 259		54	0.53	0.90	0.83
	260 or More		151	0.89	0.92	0.79
Federal Three-Mode	150 or Less	High speed	95	0.25	0.40	0.61
		Low speed	95	0.41	0.36	0.63
		Idle in neutral	95	0.45	0.63	0.06*
		Idle in drive	33	0.75	0.43	0.30*
	151 to 259	High speed	54	0.25*	0.34	0.59
		Low speed	54	0.36	0.72	0.74
		Idle in neutral	54	0.38	0.65	0.04*
		Idle in drive	45	0.78	0.66	0.13*
	260 or More	High speed	151	0.34	0.43	0.58
		Low speed	151	0.62	0.47	0.36
		Idle in neutral	151	0.49	0.82	0.24
		Idle in drive	151	0.60	0.80	0.10*

(a) CID = cubic inch displacement

(b) ST/FTP = short test/federal emission certification test procedure

(c) Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

Table 1-15. Correlation Coefficient Summary by Inertia Test Weight Group – All Three Cities

Short Test	Inertia Test Weight Group (lb)	Test Mode	No. of Vehicles	ST/FTP[(a)] Correlation Coefficients[(b)]		
				HC	CO	NO_x
Federal Short Cycle	0 to 2500		50	0.49	0.73	0.76
	2501 to 3500		119	0.76	0.86	0.81
	3501 to 4500		98	0.92	0.91	0.81
	4501 or More		33	0.73	0.88	0.77
Federal Three-Mode	0 to 2500	High speed	50	0.20*	0.53	0.54
		Low speed	50	0.33	0.42	0.50
		Idle in neutral	50	0.32	0.56	0.08*
		Idle in drive	10	0.37*	0.05*	0.33*
	2501 to 3500	High speed	119	0.41	0.50	0.62
		Low speed	119	0.55	0.61	0.64
		Idle in neutral	119	0.49	0.59	0.09*
		Idle in drive	88	0.66	0.58	0.18*
	3501 to 4500	High speed	98	0.36	0.28	0.54
		Low speed	98	0.51	0.45	0.33
		Idle in neutral	98	0.42	0.86	0.20
		Idle in drive	98	0.53	0.86	0.05*
	4501 or More	High speed	33	0.28*	0.29*	0.53
		Low speed	33	0.48	0.35	0.30*
		Idle in neutral	33	0.56	0.75	0.30*
		Idle in drive	33	0.64	0.76	0.10*

(a) ST/FTP = short test/federal emission certification test procedure

(b) Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

1.2.1.5 Effect of Emission Control System Type

The correlation coefficients of the three-city vehicle fleet are shown in Table 1-16 as a function of usage of oxidation catalysts and/or secondary air injection for control of HC and CO. In the case of the Federal Short Cycle results, the data indicate generally higher HC and CO correlations with the use of a catalyst (with or without secondary air); however, the 25 vehicles without either a catalyst or secondary air had a CO correlation coefficient (0.86) as high as the 89 vehicles with both a catalyst and secondary air injection (0.86). NO_x correlations are relatively unaffected by the use or non-use of catalysts and/or secondary air injection.

The Federal Three-Mode results are less clear. For example, in the idle in drive mode, the HC correlation coefficients for those vehicles without a catalyst (or secondary air) (0.85 and 0.86) are higher than for those vehicles with a catalyst (and secondary air) (0.46 and 0.62). The twelve vehicles without a catalyst or secondary air had a higher CO correlation coefficient (0.88) than vehicles with a catalyst (and secondary air) (0.77 and 0.67). NO_x correlations (in the high speed and low speed test modes) were relatively little affected by catalyst and secondary air usage, as in the case of the Federal Short Cycle ST.

1.2.1.6 Effect of Carburetion vs Fuel Injection

Thirty vehicles of the 300-vehicle test fleet were equipped with fuel injection. As shown in Table 1-17, the fuel injected vehicles had significantly poorer Federal Short Cycle Correlation Coefficients for all three pollutants than did the carbureted vehicles. With the Federal Three-Mode ST, this was reversed for NO_x and HC; in the high speed test mode the fuel injected NO_x coefficient (0.63) was higher than the carbureted value (0.53); and in the idle in drive test mode the fuel injected HC coefficient (0.80) was higher than the carbureted value (0.58). When the idle in neutral test mode is considered, it is seen that the HC comparison is reversed, with the fuel injected coefficient (0.36) lower than the carbureted value (0.46).

Table 1-16. Correlation Coefficient Summary by Emission Control System Type – All Three Cities

Short Test	Catalyst/Air[(a)]	Test Mode	No. of Vehicles	ST/FTP[(b)] Correlation Coefficients[(c)] HC	CO	NO_x
Federal Short Cycle	Yes/Yes		89	0.94	0.86	0.83
	Yes/No		127	0.84	0.92	0.77
	No/Yes		59	0.74	0.54	0.86
	No/No		25	0.32*	0.86	0.90
Federal Three-Mode	Yes/Yes	High speed	89	0.73	0.39	0.65
		Low speed	89	0.59	0.54	0.60
		Idle in neutral	89	0.25	0.80	0.05*
		Idle in drive	76	0.46	0.77	-0.05*
	Yes/No	High speed	127	0.13*	0.35	0.48
		Low speed	127	0.50	0.51	0.47
		Idle in neutral	127	0.56	0.65	0.12*
		Idle in drive	117	0.62	0.67	0.22
	No/Yes	High speed	59	0.34	0.40	0.65
		Low speed	59	0.36	0.52	0.74
		Idle in neutral	59	0.40	0.50	0.29
		Idle in drive	24	0.85	0.40*	0.55
	No/No	High speed	25	-0.01*	0.39*	0.28*
		Low speed	25	0.16*	-0.02*	0.47
		Idle in neutral	25	0.31*	0.69	0.40
		Idle in drive	12	0.86	0.88	0.51*

(a) Secondary air injection system

(b) ST/FTP = short test/federal emission certification test procedure

(c) Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

Table 1-17. Correlation Coefficient Summary by Fuel System Type - All Three Cities

Short Test	Fuel System Type	Test Mode	No. of Vehicles	ST/FTP[a] Correlation Coefficients[b]		
				HC	CO	NO_x
Federal Short Cycle	Fuel Injection		30	0.45	0.79	0.62
	Carburetion		270	0.82	0.89	0.82
Federal Three-Mode	Fuel Injection	High speed	30	0.11*	0.47	0.63
		Low speed	30	0.22*	0.11*	0.33*
		Idle in neutral	30	0.36	0.61	-0.20*
		Idle in drive	11	0.80	0.54*	-0.07*
	Carburetion	High speed	270	0.32	0.34	0.53
		Low speed	270	0.50	0.49	0.49
		Idle in neutral	270	0.46	0.70	0.13
		Idle in drive	218	0.58	0.69	0.11*

[a] ST/FTP = short test/federal emission certification test procedure

[b] Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

1.2.1.7 Effect of Transmission Type

Seventy-one of the 300-vehicle test fleet were equipped with manual transmissions; the remainder were equipped with automatic transmissions. Table 1-18 shows the correlation coefficients as a function of these two transmissions. With the Federal Short Cycle ST, the NO_x correlation coefficient was unaffected by transmission type, whereas both HC and CO correlation coefficients were significantly reduced for manual transmission vehicles.

In the case of the Federal Three-Mode ST, the situation is similar for NO_x. For HC and CO, the only comparative basis is the idle in neutral test mode, because the manual transmission prevents the idle in drive test mode. Here the CO correlation coefficients are similar for both transmissions (0.71 and 0.67), and the HC coefficient for the manual transmission (0.33) is considerably lower than the automatic transmission value (0.49).

1.2.1.8 Effect of Manufacturer

Table 1-19 shows the variation of correlation coefficients as a function of vehicle manufacturer. On the Federal Short Cycle, General Motors and AMC vehicles had uniformly high (0.9 and above) correlation coefficients for all three pollutants. Ford had the highest HC and CO coefficients (0.94 and 0.96, respectively), but had a lower NO_x coefficient (0.77). Chrysler had CO and NO_x coefficients similar to Ford values, but had a lower HC coefficient (0.81). The "others" category (primarily small imported vehicles) had the lowest HC (0.51) and CO (0.65) correlations, with a NO_x value (0.85) slightly higher than Ford and Chrysler values.

On the Federal Three-Mode ST, the high speed test mode resulted in generally similar NO_x correlation coefficient levels (0.64 to 0.72) for all manufacturers except General Motors, which had a value of 0.42. General Motors, Ford and "others" vehicles had slightly higher NO_x coefficients in the low speed mode than in the high speed mode. In the case of CO in the idle in drive test mode, Ford, General Motors, and AMC relative

Table 1-18. Correlation Coefficient Summary by Transmission Types – All Three Cities

Short Test	Transmission Type	Test Mode	No. of Vehicles	ST/FTP[a] Correlation Coefficients[b]		
				HC	CO	NO_x
Federal Short Cycle	Automatic		229	0.87	0.91	0.80
	Manual		71	0.42	0.66	0.82
Federal Three-Mode	Automatic	High speed	229	0.31	0.33	0.57
		Low speed	229	0.48	0.48	0.49
		Idle in neutral	229	0.49	0.71	0.11*
		Idle in drive	229	0.58	0.67	0.12*
	Manual	High speed	71	0.28	0.50	0.65
		Low speed	71	0.42	0.56	0.56
		Idle in neutral	71	0.33	0.67	0.09*
		Idle in drive	--	--	--	--

(a) ST/FTP = short test/federal emission certification test procedure

(b) Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

Table 1-19. Correlation Coefficient Summary by Manufacturer – All Three Cities

Short Test	Manu-facturer	Test Mode	No. of Vehicles	STP/FTP(a) Correlation Coefficients(b) HC	CO	NO_x
Federal Short Cycle	General Motors		99	0.90	0.90	0.92
	Ford		61	0.94	0.96	0.78
	Chrysler		36	0.81	0.94	0.77
	American Motors		18	0.94	0.91	0.93
	Others		86	0.51	0.65	0.85
Federal Three-Mode	General Motors	High speed	99	0.35	0.29	0.42
		Low speed	99	0.61	0.65	0.55
		Idle in neutral	99	0.50	0.70	0.17*
		Idle in drive	92	0.55	0.73	0.28
	Ford	High speed	61	0.33	0.43	0.65
		Low speed	61	0.40	0.53	0.67
		Idle in neutral	61	0.42	0.85	-0.10*
		Idle in drive	55	0.63	0.84	-0.25*
	Chrysler	High speed	36	0.48	0.57	0.65
		Low speed	36	0.60	0.64	0.58
		Idle in neutral	36	0.54	0.65	0.09*
		Idle in drive	36	0.56	0.68	-0.12*
	American Motors	High speed	18	0.23*	0.68	0.72
		Low speed	18	0.58	0.60	0.39*
		Idle in neutral	18	0.56	0.84	0.24*
		Idle in drive	16	0.81	0.84	0.29*
	Others	High speed	86	0.21*	0.47	0.64
		Low speed	86	0.31	0.49	0.69
		Idle in neutral	86	0.33	0.53	0.11*
		Idle in drive	30	0.82	0.32*	0.60

(a) ST/FTP = short test/federal emission certification test procedure

(b) Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

rankings were similar to those of the Federal Short Cycle; however, Chrysler CO coefficients were lower (0.68) than the other domestic manufacturers (0.73 to 0.84). The "others" category had a very low (0.32) CO coefficient in the idle in drive mode. Conversely, the HC coefficient of the "others" category in the idle in drive mode was the highest (0.82) of all manufacturer groupings. AMC also maintained a high HC coefficient (0.81) in this same test mode. The other three domestic manufacturers had similar, but lower, HC coefficients in the 0.55 to 0.63 range.

1.2.1.9 Effect of Engine Displacement and Manufacturer

The correlation coefficient summarization is extended to classification by vehicle manufacturer and engine displacement in Tables 1-20 through 1-22. The "others" category of Table 1-19 is expanded in Tables 1-20 and 1-21 to delineate the vehicles manufactured by Datsun, Toyota, VW, and Honda.

1.2.1.9.1 150 CID and Less Engine Displacement

Using the Federal Short Cycle for comparison purposes (see Table 1-20), the smaller displacement vehicles (150 CID and less) of General Motors, Datsun and Toyota have representatively high (0.82 to 0.94) NO_x correlation coefficients; Ford (0.35), Volkswagen (0.49) and Honda (0.74) are considerably lower in coefficient values. The CO coefficients of General Motors, Ford, and Datsun are representatively high (0.83 to 0.93), whereas the Toyota (0.50), Volkswagen (0.71) and Honda (0.21) values are considerably lower. All HC coefficient values are representatively high (0.84 to 0.95) except for Honda (0.20).

The Federal Three-Mode correlation coefficient results are more mixed, as might be expected from previous effect trends. In the case of NO_x, General Motors vehicles have the highest correlation coefficient (0.84) in the high speed mode; Honda (0.66) and Volkswagen (0.77) also exhibit their higher values in the high speed mode; Ford (0.61), Datsun (0.72) and Toyota (0.81) exhibit their best values in the low speed mode.

Table 1-20. Correlation Coefficient Summary for 150 CID(a) and Less by Manufacturer - All Three Cities

Short Test	Manufacturer	Test Mode	No. of Vehicles	ST/FTP(b) Correlation Coefficients(c)		
				HC	CO	NO_x
Federal Short Cycle	General Motors		12	0.84	0.89	0.94
	Ford		6	0.95	0.83	0.35*
	Datsun		8	0.95	0.93	0.89
	Toyota		9	0.88	0.50*	0.82
	VW, Audi, Porsche		21	0.88	0.71	0.49
	Honda		6	0.20*	-0.21*	0.74*
	Others		33	0.74	0.48	0.91
Federal Three-Mode	General Motors	High speed	12	0.25*	0.15*	0.84
		Low speed	12	0.61	0.70	0.32*
		Idle in drive	6	0.88	0.96	0.04*
		Idle in neutral	12	0.30*	0.66	0.19*
	Ford	High speed	6	-0.17*	0.55*	0.17*
		Low speed	6	-0.22*	0.76*	0.61*
		Idle in drive	3	-0.81*	0.93*	0.74*
		Idle in neutral	6	0.86	0.07*	0.31*
	Datsun	High speed	8	0.53*	0.93	-0.49*
		Low speed	8	0.61*	0.93	0.72
		Idle in drive	2	---	---	---
		Idle in neutral	8	0.40*	0.42*	-0.07*
	Toyota	High speed	9	0.69	-0.07*	0.56*
		Low speed	9	0.87	-0.17*	0.81
		Idle in drive	2	---	---	---
		Idle in neutral	9	0.66*	0.42*	0.00*
	VW, Audi, Porsche	High speed	21	0.20*	0.59	0.77
		Low speed	21	0.53	0.43*	0.66
		Idle in drive	5	0.77*	0.10*	0.77*
		Idle in neutral	21	0.60	0.53	0.24*
	Honda	High speed	6	0.89	0.29*	0.66*
		Low speed	6	0.23*	-0.26*	0.24*
		Idle in drive	0	---	---	---
		Idle in neutral	6	0.94	0.35*	0.62*
	Other	High speed	33	0.15*	0.47	0.61
		Low speed	33	0.23*	0.31*	0.68
		Idle in drive	15	0.84	0.44*	0.55
		Idle in neutral	33	0.37	0.41	0.37

(a) CID = cubic inch displacement

(b) ST/FTP = short test/federal emission certification test procedure

(c) Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

In the case of CO, both General Motors and Ford vehicles had high correlation coefficients (0.96 and 0.93) in the idle in drive test mode. The other vehicles in this CID class were predominantly equipped with manual transmissions and, therefore, only amenable to testing in the idle in neutral mode. On this basis, the imports ranged from 0.35 to 0.53; General Motors had 0.66, and Ford had a very low coefficient (0.07).

HC correlation coefficient results on the Federal Three-Mode ST are similarly mixed. In the idle in neutral test mode, Honda (0.94) and Ford (0.86) had the highest coefficients, Toyota (0.66) and Volkswagen (0.60) ranged in the middle, and Datsun (0.40) and General Motors (0.30) were at the lower end of the scale.

1.2.1.9.2 151 to 259 CID Engine Displacement

The medium displacement vehicles (151 to 259 CID) are segregated by manufacturer in Table 1-21. On the Federal Short Cycle ST, all domestic manufacturers have representatively high correlation coefficients for all three pollutants, except for Ford on NO_x (0.44).

In the case of the Federal Three-Mode ST, all manufacturers except AMC had their highest NO_x correlation coefficients (0.70 to 0.94) in the low speed test mode; AMC recorded 0.69 in the high speed mode and 0.49 in the low speed mode. The differences between high speed and low speed mode results for NO_x were not great except in the case of General Motors vehicles which recorded a NO_x coefficient of 0.05 in the high speed mode versus 0.81 in the low speed mode.

General Motors, Chrysler, and the "others" category had their highest CO correlation coefficients in the idle in drive mode, while Ford and AMC peaked in the idle in neutral mode. However, the differences in coefficient between these two idle test modes was small for this size engine class.

In the case of HC, General Motors and Ford vehicles had their highest correlation coefficients in the idle in neutral mode, whereas Chrysler, AMC, and the "others" vehicles peaked on the idle in drive mode.

Table 1-21. Correlation Coefficient Summary for 151 to 259 CID[(a)] by Manufacturer – All Three Cities

Short Test	Manufacturer	Test Mode	No. of Vehicles	ST/FTP[(b)] Correlation Coefficients[(c)] HC	CO	NO_x
Federal Short Cycle	General Motors		13	0.93	0.98	0.90
	Ford		13	0.92	0.93	0.44*
	Chrysler		7	0.80	0.94	0.95
	American Motors		12	0.88	0.89	0.92
	Other[(d)]		9	0.18*	0.90	0.90
Federal Three-Mode	General Motors	High speed	13	0.13*	-0.40*	0.05*
		Low speed	13	0.50*	0.87	0.81
		Idle in drive	12	0.79	0.60	-0.12*
		Idle in neutral	13	0.82	0.58	-0.09*
	Ford	High speed	13	0.79	0.91	0.67
		Low speed	13	0.79	0.91	0.70
		Idle in drive	10	0.21*	0.55*	-0.08*
		Idle in neutral	13	0.73	0.88	-0.35*
	Chrysler	High speed	7	0.70*	0.09*	0.74*
		Low speed	7	0.71*	0.18*	0.94
		Idle in drive	7	0.89	0.89	0.09*
		Idle in neutral	7	0.87	0.85	0.18*
	American Motors	High speed	12	0.03*	0.60	0.69
		Low speed	12	0.35*	0.15*	0.49*
		Idle in drive	10	0.65	0.86	0.32*
		Idle in neutral	12	0.27*	0.89	0.26*
	Other[(d)]	High speed	9	0.13*	0.08*	0.72
		Low speed	9	0.07*	0.86	0.78
		Idle in drive	6	0.68*	0.93	0.85
		Idle in neutral	9	0.02*	0.92	0.78

[(a)] CID = cubic inch displacement

[(b)] ST/FTP = short test/federal emission certification test procedure

[(c)] Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

[(d)] "Other" category includes one Datsun and one Porsche

1.2.1.9.3 260 and Greater CID Engine Displacement

Table 1-22 displays similar correlation coefficient summaries for the larger displacement vehicles (260 CID and greater), which were all domestically produced. On the Federal Short Cycle ST, all manufacturers have representatively high correlation coefficients for all three pollutants, except for AMC on CO (0.54).

Using the Federal Three-Mode ST, the high speed mode was superior for NO_x in the case of Chrysler and AMC vehicles. Although the low speed mode was superior for General Motors and Ford vehicles, the difference between high and low speed mode NO_x correlation coefficients was not large except in the case of AMC, where the high speed coefficient (0.93) was nearly three times higher than the low speed value (0.33).

The CO correlation coefficients were nearly the same in either the idle in drive or idle in neutral test modes for all manufacturers; however, the AMC values were much lower than the other manufacturers (0.36 versus 0.72 to 0.85).

The idle in drive mode resulted in the highest HC correlation coefficients for General Motors, Ford and Chrysler vehicles; however, the differences between drive and neutral coefficients was small except for Ford (0.37 in neutral versus 0.64 in drive).

The AMC vehicles had the lowest HC and CO correlation coefficients and the highest NO_x coefficients of the domestic manufacturers. In the larger engine size vehicle group, General Motors, Ford and Chrysler vehicles were generally similar in correlation coefficient level.

1.2.2 Results for Chicago

The ST/FTP correlation coefficients for the Chicago 100-vehicle test fleet are summarized in Table 1-23.

1.2.2.1 Short Test Comparison

In Chicago the Federal Short Cycle had higher correlation coefficients than the Federal Three-Mode for all three pollutants, as was

Table 1-22. Correlation Coefficient Summary for 260 CID(a) and Greater by Manufacturer – All Three Cities

Short Test	Manu-facturer	Test Mode	No. of Vehicles	ST/FTP(b) Correlation Coefficients(c)		
				HC	CO	NO_x
Federal Short Cycle	General Motors		74	0.91	0.88	0.92
	Ford		42	0.95	0.97	0.88
	Chrysler		29	0.80	0.94	0.78
	American Motors		6	0.86	0.54*	0.95
Federal Three-Mode	General Motors	High speed	74	0.37	0.40	0.56
		Low speed	74	0.71	0.63	0.68
		Idle in drive	74	0.59	0.79	0.37
		Idle in neutral	74	0.51	0.84	0.42
	Ford	High speed	42	0.20*	0.38	0.65
		Low speed	42	0.40	0.67	0.73
		Idle in drive	42	0.64	0.84	-0.19*
		Idle in neutral	42	0.37	0.85	0.01*
	Chrysler	High speed	29	0.46	0.55	0.62
		Low speed	29	0.58	0.64	0.52
		Idle in drive	29	0.59	0.74	-0.16*
		Idle in neutral	29	0.54	0.72	0.06*
	American Motors	High speed	6	0.11*	0.30*	0.93
		Low speed	6	-0.02*	0.43*	0.33*
		Idle in drive	6	0.36*	0.36*	0.82
		Idle in neutral	6	0.42*	0.36*	0.66*

(a) CID = cubic inch displacement

(b) ST/FTP = short test/federal emission certification test procedure

(c) Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

Table 1-23. Correlation Coefficient Summary – Chicago

Short Test	Test Mode	No. of Vehicles	ST/FTP[(a)] Correlation Coefficients[(b)] HC	CO	NO_x
Federal Short Cycle		100	0.88	0.82	0.81
Federal Three-Mode	High speed	100	0.12*	0.31	0.43
	Low speed	100	0.38	0.52	0.40
	Idle in neutral	100	0.42	0.52	0.03*
	Idle in drive	78	0.52	0.50	0.01*

(a) ST/FTP = short test/federal emission certification test procedure

(b) Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

the case for the entire 300-vehicle fleet (Table 1-12). The HC coefficient was higher than the pooled fleet (0.88 versus 0.78), the CO coefficient was lower (0.82 versus 0.89), and the NO_x coefficient was identical (0.81).

With the Federal Three-Mode ST, the same superior test modes were identified for Chicago as for the 300-vehicle fleet: high speed for NO_x, and idle in drive or neutral for HC and CO. Although the Federal Short Cycle HC coefficient was higher than the pooled fleet average, the idle test mode (drive or neutral) indicated that both HC and CO were lower than the fleet average. In the case of NO_x, the high speed mode indicated lower than fleet-average coefficient values, whereas the Federal Short Cycle ST predicted the same value as the fleet average.

1.2.2.2 Effect of Engine Displacement

As shown in Table 1-24, on the Federal Short Cycle ST the 150 and less CID group displayed a higher NO_x correlation coefficient and a lower CO coefficient than the other two engine size groups. The 260 and above CID group displayed the highest HC correlation.

For the Federal Three-Mode ST, the NO_x coefficient of the 150 CID or less group is lower than that of the larger engine size groups, as opposed to the opposite findings of the Federal Short Cycle ST. On the idle test mode (neutral or drive), both the HC and CO coefficients of the 150 CID or less group are lower than the larger size-engine groups.

1.2.2.3 Effect of Inertia Test Weight Group

On the Federal Short Cycle ST, as shown in Table 1-25, the smallest (2500 lb and less) and largest (4500 and greater) inertia test weight groups have the highest NO_x correlation coefficients and the lower HC and CO coefficients.

The Federal Three-Mode shows the same trends as mentioned above for HC and CO in the idle test mode (neutral or drive), but indicates lower rather than higher NO_x correlation coefficients for the 2500 lb and less inertia test weight group.

Table 1-24. Correlation Coefficient Summary by Engine Displacement - Chicago

Short Test	CID[a] Group	Test Mode	No. of Vehicles	ST/FTP[b] Correlation Coefficients[c]		
				HC	CO	NO_x
Federal Short Cycle	150 or less		32	0.84	0.77	0.90
	151 to 259		19	0.82	0.86	0.79
	260 or more		49	0.91	0.84	0.76
Federal Three-Mode	150 or less	High speed	32	0.43	0.51	0.41
		Low speed	32	0.59	0.44	0.45
		Idle in neutral	32	0.31*	0.58	0.12*
		Idle in drive	11	0.55*	0.52*	-0.03*
	151 to 259	High speed	19	0.25*	0.32*	0.31*
		Low speed	19	0.36*	0.67	0.66
		Idle in neutral	19	0.64	0.74	0.02*
		Idle in drive	18	0.71	0.71	0.20*
	260 or more	High speed	49	0.06*	0.35	0.57
		Low speed	49	0.43	0.52	0.33
		Idle in neutral	49	0.55	0.76	0.09*
		Idle in drive	49	0.61	0.80	-0.01*

(a)CID = cubic inch displacement

(b)ST/FTP = short test/federal emission certification test procedure

(c)Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

Table 1-25. Correlation Coefficient Summary by Inertia Test Weight Group – Chicago

Short Test	Inertia Test Weight Group (lb)	Test Mode	No. of Vehicles	ST/FTP[(a)] Correlation Coefficients[(b)]		
				HC	CO	NO_x
Federal Short Cycle	0 to 2500		15	0.80	0.64	0.91
	2501 to 3500		43	0.87	0.83	0.78
	3501 to 4500		30	0.93	0.88	0.77
	4501 and more		12	0.77	0.67	0.90
Federal Three-Mode	0 to 2500	High speed	15	0.27*	0.17*	0.26*
		Low speed	15	0.51	0.32*	0.40*
		Idle in neutral	15	0.14*	0.45*	-0.01*
		Idle in drive	4	-0.77*	0.28*	-0.46*
	2501 to 3500	High speed	43	0.46	0.34	0.50
		Low speed	43	0.52	0.55	0.40
		Idle in neutral	43	0.61	0.63	0.05*
		Idle in drive	32	0.79	0.66	0.33*
	3501 to 4500	High speed	30	0.01*	0.28*	0.61
		Low speed	30	0.38	0.66	0.40
		Idle in neutral	30	0.54	0.82	-0.17*
		Idle in drive	30	0.59	0.83	-0.22
	4501 and more	High speed	12	0.62	0.47*	0.58
		Low speed	12	0.54*	0.42*	0.50*
		Idle in neutral	12	0.19*	0.50*	0.60
		Idle in drive	12	0.43*	0.64	0.56*

(a) ST/FTP = short test/federal emission certification test procedure

(b) Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

1.2.2.4 Effect of Emission Control System Type

As shown in Table 1-26 the use or non-use of oxidation catalysts and/or secondary air injection for control of HC and CO does not produce readily discernible trends with the Federal Short Cycle ST, except that the lowest NO_x correlation coefficients are achieved when no secondary air injection is present.

When Federal Three-Mode ST results are compared, little difference in NO_x discrimination is noted, except for the catalyst without secondary air case, which has the lowest NO_x correlation coefficient (when comparing results from either the low or high speed test modes). However, the presence of secondary air does seem to result in higher NO_x coefficients in the high and low speed test modes. In the case of HC and CO, again little substantive trend information is present, except that the catalyst with secondary air configuration has the lowest HC coefficient (in either idle in drive or idle in neutral test modes).

1.2.2.5 Effect of Carburetion vs Fuel Injection

In the Chicago fleet, as shown in Table 1-27, there is little substantive difference between fuel injection and carburetion for the correlation coefficients of all three pollutants on the Federal Short Cycle ST. On the Federal Three-Mode ST, however, fuel injected vehicles achieved significantly higher HC and CO coefficients in the idle test mode.

1.2.2.6 Effect of Transmission Type

The 22 vehicles equipped with manual transmissions and the 78 with automatic transmissions in the Chicago fleet had essentially equivalent HC, CO, and NO_x correlation when tested on the Federal Short Cycle ST (see Table 1-28), although the manual transmission class had the highest NO_x coefficient and the lowest HC coefficient. These same general trends were observed on the Federal Three-Mode ST, using either the high or low speed mode for NO_x and the idle in neutral mode for HC and CO comparative purposes.

Table 1-26. Correlation Coefficient Summary by Emission Control System Type - Chicago

Short Test	Catalyst/Air[(a)]	Test Mode	No. of Vehicles	ST/FTP[(b)] Correlation Coefficients[(c)] HC	CO	NO_x
Federal Short Cycle	Yes/Yes		30	0.91	0.76	0.80
	Yes/No		44	0.86	0.85	0.77
	No/Yes		17	0.91	0.92	0.94
	No/No		9	0.81	0.82	0.70
Federal Three-Mode	Yes/Yes	High speed	30	0.30*	0.49*	0.60
		Low speed	30	0.14*	0.51	0.69
		Idle in neutral	30	0.23*	0.64	-0.05*
		Idle in drive	27	0.47	0.58	-0.11*
	Yes/No	High speed	44	0.03*	0.32	0.44
		Low speed	44	0.52	0.56	0.36
		Idle in neutral	44	0.46	0.48	0.10*
		Idle in drive	42	0.59	0.60	0.20*
	No/Yes	High speed	17	0.52	0.48*	0.56
		Low speed	17	0.68	0.72	0.69
		Idle in neutral	17	0.75	0.54	0.18*
		Idle in drive	5	0.88	0.38*	0.25*
	No/No	High speed	9	-0.10*	0.36*	0.04*
		Low speed	9	0.36*	-0.07*	0.68
		Idle in neutral	9	0.75	0.85	-0.04*
		Idle in drive	4	0.88*	0.82*	-0.74*

(a) Secondary air injection system

(b) ST/FTP = short test/federal emission certification test procedure

(c) Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

Table 1-27. Correlation Coefficient Summary by Fuel System Type – Chicago

Short Test	Fuel Injection	Test Mode	No. of Vehicles	ST/FTP[a] Correlation Coefficients[b]		
				HC	CO	NO_x
Federal Short Cycle	Yes		10	0.79	0.82	0.75
	No		90	0.88	0.82	0.81
Federal Three-Mode	Yes	High speed	10	-0.07*	0.01*	0.52*
		Low speed	10	0.03*	0.31*	0.15*
		Idle in neutral	10	0.91	0.83	-0.64
		Idle in drive	4	0.95*	0.90*	-0.99
	No	High speed	90	0.11*	0.32	0.44
		Low speed	90	0.39	0.53	0.40
		Idle in neutral	90	0.40	0.54	0.05*
		Idle in drive	74	0.51	0.53	0.02*

[a] ST/FTP = short test/federal emission certification test procedure

[b] Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

Table 1-28. Correlation Coefficient Summary by Transmission Type – Chicago

Short Test	Transmission Type	Test Mode	No. of Vehicles	ST/FTP[a] Correlation Coefficients[b]		
				HC	CO	NO_x
Federal Short Cycle	Automatic		78	0.89	0.82	0.80
	Manual		22	0.82	0.84	0.89
Federal Three-Mode	Automatic	High speed	78	0.09*	0.30	0.47
		Low speed	78	0.35	0.53	0.38
		Idle in neutral	78	0.50	0.55	0.01*
		Idle in drive	78	0.52	0.50	0.01*
	Manual	High speed	22	0.57	0.61	0.57
		Low speed	22	0.73	0.69	0.54
		Idle in neutral	22	0.31	0.48	0.18*
		Idle in drive	--	----	----	----

[a] ST/FTP = short test/federal emission certification test procedure

[b] Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

1.2.2.7 Effect of Manufacturer

Table 1-29 shows the variation of correlation coefficients as a function of vehicle manufacturer for the Chicago fleet. On the Federal Short Cycle ST, the principal discernible trend is the lower HC and NO_x coefficients achieved by Chrysler vehicles. When tested on the Federal Three-Mode ST, the Chrysler vehicles improved in NO_x discrimination on a relative basis (when comparing readings of either the high or low speed test modes). The idle test mode (in neutral or drive) indicated that Chrysler vehicles had the lowest HC and CO coefficients, with AMC vehicles having very high HC and CO coefficients (the same level of coefficient obtained by AMC vehicles on the Federal Short Cycle ST).

1.2.3 Results for Houston

The ST/FTP correlation coefficients for the Houston 100-vehicle test fleet are summarized in Table 1-30.

1.2.3.1 Short Test Comparison

In Houston the Federal Short Cycle ST had higher correlation coefficients than the Federal Three-Mode ST for all three pollutants, as was the case for the entire 300-vehicle fleet (Table 1-12). The HC coefficient was higher than the pooled fleet (0.91 versus 0.78); the CO coefficient was also higher (0.97 versus 0.89); and the NO_x coefficient was slightly lower (0.78 versus 0.81).

With the Federal Three-Mode ST, the same superior NO_x test mode (high speed) was identified as for the 300-vehicle fleet and Chicago vehicles. The idle mode (neutral or drive) was also the superior CO test mode, as in the case of the pooled fleet and Chicago. However, in the case of HC, both the low and high speed test modes were superior to the idle test mode, with the low speed mode having the highest HC coefficient (0.76); this singular result was not obtained in any other city but Houston. For the pooled 300-vehicle fleet the low speed mode had a slightly higher coefficient (0.47) than the idle in neutral coefficient (0.45) but was lower than the idle in drive coefficient (0.58).

Table 1-29. Correlation Coefficient Summary by Manufacturer – Chicago

Short Test	Manufacturer	Test Mode	No. of Vehicles	ST/FTP[a] Correlation Coefficients[b]		
				HC	CO	NO_x
Federal Short Cycle	General Motors		33	0.91	0.88	0.95
	Ford		20	0.96	0.75	0.84
	Chrysler		12	0.74	0.88	0.43*
	American Motors		6	0.94	0.93	0.96
	Others		29	0.80	0.86	0.89
Federal Three-Mode	General Motors	High speed	33	0.04*	0.34*	0.51
		Low speed	33	0.58	0.60	0.50
		Idle in neutral	33	0.51	0.57	0.13*
		Idle in drive	31	0.61	0.71	0.37
	Ford	High speed	20	0.38*	0.52	0.64
		Low speed	20	0.02*	0.80	0.75
		Idle in neutral	20	0.38*	0.70	-0.38*
		Idle in drive	19	0.61	0.84	-0.15*
	Chrysler	High speed	12	-0.29*	0.35*	0.23*
		Low speed	12	-0.37*	-0.10*	0.54*
		Idle in neutral	12	0.33*	0.39*	-0.31*
		Idle in drive	12	0.30*	0.47*	-0.43*
	American Motors	High speed	6	0.50*	0.64*	0.96
		Low speed	6	0.54*	0.63*	0.06*
		Idle in neutral	6	0.90	0.89	-0.38*
		Idle in drive	6	0.92	0.84	0.26*
	Others	High speed	29	0.34*	0.19*	0.42
		Low speed	29	0.57	0.77	0.61
		Idle in neutral	29	0.40	0.56	0.12*
		Idle in drive	10	0.70	0.33*	0.08*

[a] ST/FTP = short test/federal emission certification test procedure

[b] Correlation coefficients are statistically significant at the 95 percent program confidence level except where indicated by an asterisk

Table 1-30. Correlation Coefficient Summary — Houston

Short Test	Test Mode	No. of Vehicles	ST/FTP[a] Correlation Coefficients[b] HC	CO	NO_x
Federal Short Cycle		100	0.91	0.97	0.78
Federal Three-Mode	High speed	100	0.66	0.45	0.44
	Low speed	100	0.76	0.53	0.41
	Idle in neutral	100	0.47	0.79	0.34
	Idle in drive	75	0.60	0.76	0.36

[a] ST/FTP = short test/federal emission certification test procedure

[b] Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

1.2.3.2 Effect of Engine Displacement

On the basis of the Federal Short Cycle ST (see Table 1-31) the only discernible trends for the Houston vehicles are the lower CO coefficient for the 150 CID or less group and the lower NO_x coefficient for the 151 to 159 CID group. When the high and low speed test modes of the Federal Three-Mode ST are compared, the NO_x coefficient of the 151 to 159 CID group is essentially the same as the 260 or more CID group, but is lower than the 150 or less CID group. The three-mode results for HC and CO are of such variability that trends with respect to engine size are not readily apparent.

1.2.3.3 Effect of Inertia Test Weight Group

Examination of the Houston vehicles by inertia test weight grouping (see Table 1-32) on the Federal Short Cycle ST does not reveal significant trends, other than the relatively poor NO_x correlation coefficient of the 4500 lb and above class. This same characteristic is shown by the Federal Three-Mode ST results in all test modes. The three-mode HC and CO results also do not indicate significant trends with inertia weight.

1.2.3.4 Effect of Emission Control System Type

As indicated in Table 1-33, the use or non-use of catalysts and/or secondary air injection for control of HC and CO in the Houston fleet does not produce readily discernible trends with the Federal Short Cycle ST.

On the Federal Three-Mode ST, however, the presence of secondary air does seem to result in higher NO_x correlation coefficients in the high and low speed test modes (which was also noted above for the Chicago fleet). Also, the use of a catalyst plus secondary air seems to result in high HC correlation in both high and low speed test modes and low HC correlations in the idle test mode. This latter trend was not seen in the Chicago data, but is present in the pooled fleet data of Table 1-16.

Table 1-31. Correlation Coefficient Summary by Engine Displacement - Houston

Short Test	CID(a) Group	Test Mode	No. of Vehicles	ST/FTP(b) Correlation Coefficients(c)		
				HC	CO	NO_x
Federal Short Cycle	150 or less		33	0.90	0.82	0.78
	151 to 259		16	0.94	0.96	0.56
	260 or more		51	0.94	0.98	0.79
Federal Three-Mode	150 or less	High speed	33	0.29*	0.33*	0.61
		Low speed	33	0.53	0.38	0.66
		Idle in neutral	33	0.61	0.79	0.42
		Idle in drive	11	0.92	0.45*	0.85
	151 to 259	High speed	16	-0.14*	-0.31*	0.32*
		Low speed	16	0.86	0.95	0.56
		Idle in neutral	16	0.82	0.68	0.34*
		Idle in drive	13	0.90	0.75	0.57
	260 or more	High speed	51	0.75	0.65	0.54
		Low speed	51	0.83	0.59	0.31
		Idle in neutral	51	0.40	0.84	0.35
		Idle in drive	51	0.57	0.76	0.31

(a) CID = cubic inch displacement

(b) ST/FTP = short/test federal emission certification test procedure

(c) Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

Table 1-32. Correlation Coefficient Summary by Inertia Test Weight Group – Houston

Short Test	Inertia Test Weight Group (lb)	Test Mode	No. of Vehicles	STP/FTP(a) Correlation Coefficients(b)		
				HC	CO	NO_x
Federal Short Cycle	0 to 2500		19	0.94	0.87	0.89
	2501 to 3500		38	0.88	0.95	0.73
	3501 to 4500		33	0.94	0.98	0.81
	4501 or more		10	0.93	0.98	0.53*
Federal Three-Mode	0 to 2500	High speed	19	0.47	0.58	0.65
		Low speed	19	0.81	0.57	0.44*
		Idle in neutral	19	0.82	0.67	0.54
		Idle in drive	3	1.00	-0.90*	0.99*
	2501 to 3500	High speed	38	0.66	0.70	0.57
		Low speed	38	0.75	0.64	0.68
		Idle in neutral	38	0.52	0.68	0.31*
		Idle in drive	29	0.70	0.62	0.33*
	3501 to 4500	High speed	33	0.87	0.42	0.45
		Low speed	33	0.85	0.44	0.12*
		Idle in neutral	33	0.25*	0.93	0.41
		Idle in drive	33	0.43	0.91	0.37
	4501 or more	High speed	10	0.49*	0.69	0.21*
		Low speed	10	0.66	0.55*	0.14*
		Idle in neutral	10	0.62*	0.85	0.33*
		Idle in drive	10	0.75	0.85	0.27*

(a) ST/FTP = short test/federal emission certification test procedure

(b) Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

Table 1-33. Correlation Coefficient Summary by Emission Control System Type – Houston

Short Test	Catalyst/ Air[a]	Test Mode	No. of Vehicles	ST/FTP[b] Correlation Coefficients[c]		
				HC	CO	NO_x
Federal Short Cycle	Yes/Yes		27	0.97	0.90	0.84
	Yes/No		41	0.91	0.98	0.70
	No/Yes		22	0.94	0.87	0.75
	No/No		10	0.98	0.91	0.94
Federal Three-Mode	Yes/Yes	High speed	27	0.94	0.41	0.78
		Low speed	27	0.94	0.57	0.64
		Idle in neutral	27	0.14*	0.79	0.09*
		Idle in drive	24	0.40*	0.82	0.17*
	Yes/No	High speed	41	0.56	0.64	0.27*
		Low speed	41	0.76	0.63	0.36
		Idle in neutral	41	0.59	0.75	0.52
		Idle in drive	38	0.68	0.69	0.54
	No/Yes	High speed	22	0.33*	0.56	0.61
		Low speed	22	0.32*	0.64	0.74
		Idle in neutral	22	0.40*	0.64	0.62
		Idle in drive	9	0.92	0.76	0.84
	No/No	High speed	10	0.55*	0.93	-0.09*
		Low speed	10	0.86	-0.01*	0.11*
		Idle in neutral	10	0.80	0.90	0.62*
		Idle in drive	4	0.70*	0.56*	0.43*

(a) Secondary air injection system

(b) ST/FTP = short test/federal emission certification test procedure

(c) Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

1.2.3.5 Effect of Carburetion vs Fuel Injection

In the Houston Fleet, as shown in Table 1-34, the fuel injected vehicles had substantially lower CO and NO_x correlation coefficients when tested on the Federal Short Cycle ST. This was not evident in the Chicago fleet, but was reflected in the results for the pooled fleet (Table 1-17). On the Federal Three-Mode ST, the fuel injected vehicles achieved significantly higher HC coefficients in the idle test mode, which was also observed in the Chicago fleet (Table 1-27).

1.2.3.6 Effect of Transmission Type

The vehicles in the Houston fleet with manual and automatic transmissions had essentially equivalent HC, CO and NO_x correlations when tested in the Federal Short Cycle ST (see Table 1-35). When tested on the Federal Three-Mode ST, they again had similar levels of NO_x coefficients in the high and low speed test modes and similar levels of CO coefficients in the idle in neutral mode.

1.2.3.7 Effect of Manufacturer

Table 1-36 shows the variation of correlation coefficients as a function of vehicle manufacturer for the Houston fleet. On the Federal Short Cycle ST, the principal discernible trends are the lower NO_x correlation coefficients achieved by the Chrysler and Ford vehicles (Chrysler was similarly low in the Chicago fleet). On the Federal Three-Mode ST, in either high or low speed test modes, the Chrysler and Ford vehicles improved in NO_x discrimination relative to the other vehicles. In the idle test mode, there is little discernible difference in CO discrimination capability. In terms of HC coefficient in the idle mode, however, the AMC vehicles were superior and General Motors vehicles had the lowest values.

1.2.4 Results for Phoenix

The ST/FTP correlation coefficients for the Phoenix 100-vehicle test fleet are summarized in Table 1-37.

Table 1-34. Correlation Coefficient Summary by Fuel System Type - Houston

Short Test	Fuel System Type	Test Mode	No. of Vehicles	ST/FTP[a] Correlation Coefficients[b]		
				HC	CO	NO_x
Federal Short Cycle	Fuel injection		10	0.97	0.76	0.53*
	Carburetion		90	0.91	0.97	0.78
Federal Three-Mode	Fuel injection	High speed	10	0.51*	0.77	0.48*
		Low speed	10	0.82	0.0*	-0.08*
		Idle in neutral	10	0.86	0.77	0.14*
		Idle in drive	3	0.99*	0.47*	0.57*
	Carburetion	High speed	90	0.67	0.45	0.46
		Low speed	90	0.77	0.61	0.44
		Idle in neutral	90	0.45	0.81	0.35
		Idle in drive	72	0.60	0.76	0.36

(a) ST/FTP = short test/federal emission certification test procedure

(b) Correlation Coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

Table 1-35. Correlation Coefficient Summary by Transmission Type - Houston

Short Test	Transmission Type	Test Mode	No. of Vehicles	ST/FTP(a) Correlation Coefficients(b)		
				HC	CO	NO_x
Federal Short Cycle	Automatic		75	0.91	0.97	0.78
	Manual		25	0.93	0.91	0.72
Federal Three-Mode	Automatic	High speed	75	0.69	0.47	0.55
		Low speed	75	0.79	0.60	0.45
		Idle in neutral	75	0.44	0.84	0.34
		Idle in drive	75	0.60	0.76	0.36
	Manual	High speed	25	0.40	0.24*	0.49
		Low speed	25	0.72	0.31*	0.46
		Idle in neutral	25	0.73	0.80	0.48
		Idle in drive	--	--	--	--

(a) ST/FTP = short test/federal emission certification procedure

(b) Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

Table 1-36. Correlation Coefficient Summary by Manufacturer – Houston

Short Test	Manufacturer	Test Mode	No. of Vehicles	ST/FTP(a) Correlation Coefficients(b)		
				HC	CO	NO_x
Federal Short Cycle	General Motors		33	0.94	0.97	0.90
	Ford		21	0.93	0.98	0.66
	Chrysler		12	0.92	0.98	0.57*
	American Motors		6	0.98	0.90	0.97
	Others		28	0.91	0.79	0.90
Federal Three-Mode	General Motors	High speed	33	0.85	0.52	0.20*
		Low speed	33	0.88	0.81	0.51
		Idle in neutral	33	0.42	0.78	0.50
		Idle in drive	30	0.48	0.73	0.51
	Ford	High speed	21	0.02*	0.70	0.66
		Low speed	21	0.72	0.88	0.69
		Idle in neutral	21	0.39*	0.85	0.12*
		Idle in drive	19	0.68	0.85	-0.08*
	Chrysler	High speed	12	0.66	0.73	0.34*
		Low speed	12	0.79	0.75	0.53*
		Idle in neutral	12	0.62	0.78	0.58
		Idle in drive	12	0.69	0.78	0.59
	American Motors	High speed	6	-0.68*	0.82	0.55*
		Low speed	6	0.77*	0.79*	0.06*
		Idle in neutral	6	0.82	0.77*	0.18*
		Idle in drive	5	0.86*	0.69*	0.41*
	Others	High speed	28	0.33*	0.58	0.71
		Low speed	28	0.54	0.32*	0.73
		Idle in neutral	28	0.59	0.60	0.48
		Idle in drive	9	0.92	0.09*	0.92

(a) ST/FTP = short test/federal emission certification test procedure

(b) Correlation Coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

Table 1-37. Correlation Coefficient Summary — Phoenix

Short Test	Test Mode	No. of Vehicles	ST/FTP(a) Correlation Coefficients(b)		
			HC	CO	NO_x
Federal Short Cycle		100	0.45	0.76	0.85
Federal Three-Mode	High speed	100	0.25	0.32	0.73
	Low speed	100	0.28	0.41	0.66
	Idle in neutral	100	0.44	0.80	0.03*
	Idle in drive	76	0.71	0.81	-0.05*

(a) ST/FTP = short test/federal emission certification test procedure

(b) Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

1.2.4.1 Short Test Comparison

The Federal Short Cycle ST resulted in a NO_x correlation for the Phoenix fleet that was higher than any other city and the pooled three-city fleet (see Table 1-12), 0.85 versus the fleet average of 0.81. Similarly, the NO_x coefficients for the high and low speed test modes of the Federal Three-Mode ST were higher than any other city or the pooled fleet average. The high speed mode value (0.73) was not too far below the fleet average for NO_x on the Federal Short Cycle ST (0.81).

The HC coefficient on the Federal Short Cycle was the lowest observed in any city (0.45 versus 0.88 in Chicago and 0.91 in Houston). Conversely, the idle in drive HC coefficient of the Federal Three-Mode ST was the highest observed in any city (0.71 versus 0.52 in Chicago and 0.60 in Houston).

In terms of CO correlation, the Phoenix Federal Short Cycle ST value was the lowest observed (0.76 versus 0.82 in Chicago and 0.97 in Houston). Again, the idle in drive CO coefficient of the Federal Three-Mode ST (0.81) was higher than the Federal Short Cycle value (0.76) and higher than any idle in drive value in the other cities (0.50 in Chicago and 0.76 in Houston).

In Phoenix, the high speed mode and idle in drive mode were clearly superior for NO_x and HC/CO discrimination, respectively, for the Federal Three-Mode ST.

1.2.4.2 Effect of Engine Displacement

For the Federal Short Cycle ST (see Table 1-38), it is seen that the two smaller size engine groups (150 or less CID and 151 to 259 CID) were responsible for the low overall HC correlation coefficient observed in Phoenix. In the case of CO, the 150 or less CID had a very low (0.36) coefficient.

Using the Federal Three-Mode ST, the NO_x coefficients on the high and low speed test modes are largely insensitive to engine size,

Table 1-38. Correlation Coefficient Summary by Engine Displacement – Phoenix

Short Test	CID(a) Group	Test Mode	No. of Vehicles	ST/FTP(b) Correlation Coefficients(c)		
				HC	CO	NO_x
Federal Short Cycle	150 or less		30	0.42	0.36	0.80
	151 to 259		19	0.33*	0.93	0.95
	260 or more		51	0.70	0.82	0.83
Federal Three-Mode	150 or less	High speed	30	0.23*	0.52	0.85
		Low speed	30	0.29*	0.18*	0.82
		Idle in neutral	30	0.34*	0.74	-0.18*
		Idle in drive	11	0.65	0.46*	-0.21*
	151 to 259	High speed	19	0.36*	0.60	0.81
		Low speed	19	0.27*	0.62	0.87
		Idle in neutral	19	0.13*	0.76	0.14*
		Idle in drive	14	0.80	0.86	-0.14*
	260 or more	High speed	51	0.16*	0.31	0.75
		Low speed	51	0.28	0.43	0.49
		Idle in neutral	51	0.71	0.87	0.22*
		Idle in drive	51	0.76	0.87	-0.02*

(a) CID = cubic inch displacement

(b) ST/FTP = short test/federal emission certification test procedure

(c) Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

although there is some dropoff in coefficient (to 0.49) for the 260 and higher CID group in the low speed mode.

The idle in drive mode does not indicate the severe reduction in HC coefficient observed with the Federal Short Cycle ST for the two smaller engine size groups; however, the idle in neutral mode does indicate this effect.

The idle in drive mode, on the other hand, does indicate a reduction in CO coefficient for the 150 or less CID group, whereas the idle in neutral mode does not. Thus, the idle in drive mode follows the CO trends of the Federal Short Cycle and the idle in neutral mode follows the HC trends of the Federal Short Cycle.

1.2.4.3 Effect of Inertia Test Weight Group

As shown in Table 1-39, the low HC coefficient for the Phoenix fleet in the Federal Short Cycle ST is seen to be associated with both small (2500 lb and less) and large (4500 lb and higher) vehicles (0.21 and 0.28 respectively). This same effect is also shown for the CO coefficient. Also, the NO_x coefficient for the smallest vehicle size group is considerably below the other inertia weight groups.

Using the Federal Three-Mode ST, the small size vehicles (2500 lb and less) actually display the highest NO_x correlations of the four vehicle weight groups in the high and low speed test modes, in opposition to the findings of the Federal Short Cycle ST. The HC and CO trends are less clear, although the idle in neutral HC results tend to follow the Federal Short Cycle results (2500 and 4500 lb groups have lower HC coefficients) and the idle in drive CO results also follow the Federal Short Cycle results (the 2500 lb group has a lower CO coefficient).

1.2.4.4 Effect of Emission Control System Type

As indicated in Table 1-40, the use or non-use of catalysts and/or secondary air injection for control of HC and CO in the Phoenix fleet provides no meaningful trend for NO_x discrimination based on the Federal

Table 1-39. Correlation Coefficient Summary by Inertia Test Weight Group – Phoenix

Short Test	Inertia Test Weight Group (lb)	Test Mode	No. of Vehicles	ST/FTP[a] Correlation Coefficients[b]		
				HC	CO	NO_x
Federal Short Cycle	0 to 2500		16	0.21*	0.57	0.44*
	2501 to 3500		38	0.52	0.71	0.91
	3501 to 4500		35	0.86	0.83	0.86
	4501 or more		11	0.28*	0.68	0.80
Federal Three-Mode	0 to 2500	High speed	16	0.15*	0.68	0.35
		Low speed	16	0.13*	0.17*	0.89
		Idle in neutral	16	0.15*	0.80	0.02*
		Idle in drive	3	0.99*	0.55*	0.80*
	2501 to 3500	High speed	38	0.56	0.56	0.80
		Low speed	38	0.64	0.70	0.79
		Idle in neutral	38	0.49	0.80	0.03*
		Idle in drive	27	0.71	0.82	-0.25*
	3501 to 4500	High speed	35	0.29*	0.41	0.72
		Low speed	35	0.29*	0.43	0.53
		Idle in neutral	35	0.82	0.82	0.35
		Idle in drive	35	0.82	0.84	0.20*
	4501 or more	High speed	11	-0.03*	0.01*	0.76
		Low speed	11	0.08*	0.09*	0.36*
		Idle in neutral	11	0.38*	0.76	0.04*
		Idle in drive	11	0.52*	0.81	-0.24*

(a) ST/FTP = short test/federal emission certification test procedure

(b) Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

(c) Only two data points used

Table 1-40. Correlation Coefficient Summary by Emission Control System Type – Phoenix

Short Test	Catalyst/Air[(a)]	Test Mode	No. of Vehicles	ST/FTP[(b)] Correlation Coefficients[(c)] HC	CO	NO_x
Federal Short Cycle	Yes/Yes		32	0.92	0.93	0.86
	Yes/No		42	0.62	0.75	0.82
	No/Yes		20	0.51	0.22*	0.92
	No/No		6	-0.70*	0.83	0.94
Federal Three-Mode	Yes/Yes	High speed	32	0.54	0.47	0.79
		Low speed	32	0.61	0.54	0.71
		Idle in neutral	32	0.73	0.96	0.17*
		Idle in drive	25	0.87	0.96	-0.21*
	Yes/No	High speed	42	0.20*	0.31	0.68
		Low speed	42	0.25*	0.44	0.62
		Idle in neutral	42	0.63	0.73	-0.13*
		Idle in drive	37	0.66	0.73	-0.17*
	No/Yes	High speed	20	0.36*	0.38*	0.79
		Low speed	20	0.34*	0.38*	0.86
		Idle in neutral	20	0.13*	0.45	0.05*
		Idle in drive	10	0.55*	0.57*	0.41*
	No/No	High speed	6	-0.29*	-0.21*	0.70*
		Low speed	6	-0.56*	0.07*	0.86
		Idle in neutral	6	-0.92	0.58*	0.48*
		Idle in drive	4	0.54*	0.38*	0.41*

(a) Secondary air injection system

(b) ST/FTP = short test/federal emission certification test procedure

(c) Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

Short Cycle ST. In the case of HC and CO, it only appears that a catalyst plus air injection improves both HC and CO correlation coefficients.

With the Federal Three-Mode ST, observations similar to those on the Federal Short Cycle are apparent for NO_x and HC/CO.

1.2.4.5 Effect of Carburetion vs Fuel Injection

In the Phoenix fleet, as shown in Table 1-41, the fuel injected vehicles had decidedly poorer HC and NO_x correlations when tested on the Federal Short Cycle. Conversely, the CO correlation coefficient for fuel injected vehicles was higher (0.88) than for the carbureted vehicles (0.76).

On the Federal Three-Mode ST, the NO_x trend was reversed, with the fuel injected vehicles having higher NO_x coefficients. In the case of HC, the idle in drive results were essentially the same while the idle in neutral results showed much higher coefficients for the carbureted vehicles. For CO, carbureted vehicles had higher coefficients in the idle test mode (drive or neutral), and thus displayed an effects trend opposite that observed from the Federal Short Cycle results.

1.2.4.6 Effect of Transmission Type

Based on the Phoenix data shown in Table 1-42, the vehicles with automatic transmissions had significantly higher HC and CO correlation coefficients when tested on the Federal Short Cycle ST. The NO_x coefficients were insensitive to transmission type.

The Federal Three-Mode ST results are similar in the case of NO_x. In the idle in neutral comparative case, the higher HC and CO coefficients of the automatic transmission vehicles were in direct agreement with the Federal Short Cycle trends for these pollutants.

1.2.4.7 Effect of Manufacturer

Table 1-43 shows the variation of correlation coefficients as a function of vehicle manufacturer for the Phoenix fleet. On the Federal Short Cycle ST, the most discernible feature is the extremely low HC

Table 1-41. Correlation Coefficient Summary by Fuel System Type – Phoenix

Short Test	Fuel System Type	Test Mode	No. of Vehicles	ST/FTP[a] Correlation Coefficients[b]		
				HC	CO	NO_x
Federal Short Cycle	Fuel Injection		10	0.24*	0.88	0.50*
	Carburetion		90	0.58	0.76	0.86
Federal Three-Mode	Fuel Injection	High speed	10	0.05*	0.60*	0.83
		Low speed	10	0.01*	0.13*	0.75
		Idle in neutral	10	-0.05*	0.68	-0.11
		Idle in drive	4	0.73	-0.18*	0.09*
	Carburetion	High speed	90	0.32	0.34	0.72
		Low speed	90	0.36	0.42	0.64
		Idle in neutral	90	0.62	0.81	0.10*
		Idle in drive	72	0.71	0.82	-0.07*

[a] ST/FTP = short test/federal emission certification test procedure

[b] Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

Table 1-42. Correlation Coefficient Summary by Transmission Type – Phoenix

Short Test	Transmission Type	Test Mode	No. of Vehicles	ST/FTP[a] Correlation Coefficients[b]		
				HC	CO	NO_x
Federal Short Cycle	Automatic		76	0.72	0.82	0.83
	Manual		24	0.19*	0.53	0.89
	Automatic	High speed	76	0.24	0.26	0.74
		Low speed	76	0.29	0.38	0.64
		Idle in neutral	76	0.65	0.81	0.13*
		Idle in drive	76	0.71	0.81	0.05*
	Manual	High speed	24	0.29*	0.73	0.89
		Low speed	24	0.29*	0.73	0.77
		Idle in neutral	24	0.18*	0.75	-0.12*
		Idle in drive	--	----	----	----

[a] ST/FTP = short test/federal emission certification test procedure

[b] Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

Table 1-43. Correlation Coefficient Summary by Manufacturer - Phoenix

Short Test	Manufacturer	Test Mode	No. of Vehicles	ST/FTP[a] Correlation Coefficients[b]		
				HC	CO	NO_x
Federal Short Cycle	General Motors		33	0.80	0.82	0.93
	Ford		20	0.94	0.97	0.95
	Chrysler		12	-0.01*	0.72	0.94
	American Motors Company		6	0.95	0.89	0.91
	Others		29	0.17*	0.34*	0.78
Federal Three-Mode	General Motors	High speed	33	0.25*	0.40	0.60
		Low speed	33	0.32*	0.59	0.67
		Idle in neutral	33	0.75	0.77	-0.02*
		Idle in drive	31	0.83	0.77	-0.22*
	Ford	High speed	20	0.60	0.41*	0.87
		Low speed	20	0.64	0.49	0.73
		Idle in neutral	20	0.78	0.96	-0.26*
		Idle in drive	17	0.85	0.96	-0.47*
	Chrysler	High speed	12	-0.05*	0.30*	0.91
		Low speed	12	-0.09*	0.22*	0.59
		Idle in neutral	12	0.19*	0.66	0.36*
		Idle in drive	12	0.13*	0.72	0.34*
	AMC	High speed	6	0.69*	0.45*	0.82
		Low speed	6	0.89	0.87	0.77*
		Idle in neutral	6	0.96	0.96	0.28*
		Idle in drive	5	0.99	1.00	-0.38*
	Others	High speed	29	0.13*	0.63	0.82
		Low speed	29	0.13*	0.34*	0.86
		Idle in neutral	29	0.05*	0.62	0.04*
		Idle in drive	11	0.68	0.32*	0.59*

[a] ST/FTP = short test/federal emission certification test procedure

[b] Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

correlation coefficient of the Chrysler vehicles. This same characteristic is displayed by the idle test mode of the Federal Three-Mode ST for Chrysler vehicles.

The high and low speed mode NO_x results of the Federal Three-Mode agree with the Federal Short Cycle NO_x trends, and the idle mode CO results of the Three-Mode ST agree with the Federal Short Cycle CO trends.

1.3 CONTINGENCY TABLE ANALYSIS DISCUSSION

1.3.1 Hydrocarbon Emission

The variation of E_c, E_o, and FF as a function of HC cut-point was determined for each ST. The results for the pooled fleet with the Federal Short Cycle and the Federal Three-Mode STs are shown graphically in Figures 1-4 and 1-5 to indicate the general nature of the tradeoffs available. As can be seen, reducing the E_c increases E_o and decreases FF.

Table 1-44 summarizes the results for both STs for the pooled fleet (300 vehicles) and the individual city fleets (100 vehicles each) at the specific E_c analysis value of 5 percent. This value was used in the analysis to set HC ST cut-points based on the total pooled fleet population. These same numerical cut-points were then used in subsequent contingency analyses on an individual city and test mode basis. As a consequence, the resultant actual E_c values for the individual cities or test modes vary from the 5 percent E_c value for the pooled fleet due to differences in observed emission characteristics between the pooled fleet and the individual city fleets.

Also shown in Table 1-44 are the effectiveness values (STE) and the rejection ratio values (STRR) for each test or test mode.

In the case of the Federal Three-Mode ST, it is clear that the idle-in-drive test mode is the superior mode for HC discrimination for each city and the pooled fleet; the STE value ranges from 0.349 to 0.405 for for the city fleets and is 0.375 for the pooled fleet. In comparison, the STE value for the Federal Short Cycle ST ranges from 0.530 to 0.691 for the city fleets and is 0.589 for the pooled fleet.

Although the idle in neutral test mode is not as effective as the idle in drive mode, its STE value is approximately 90 percent of the idle in drive STE value; thus, it would appear appropriate to use that mode for cars not equipped with an automatic transmission.

As can be seen in Table 1-44, the STRR values are below one for both STs for all cities and the pooled fleet.

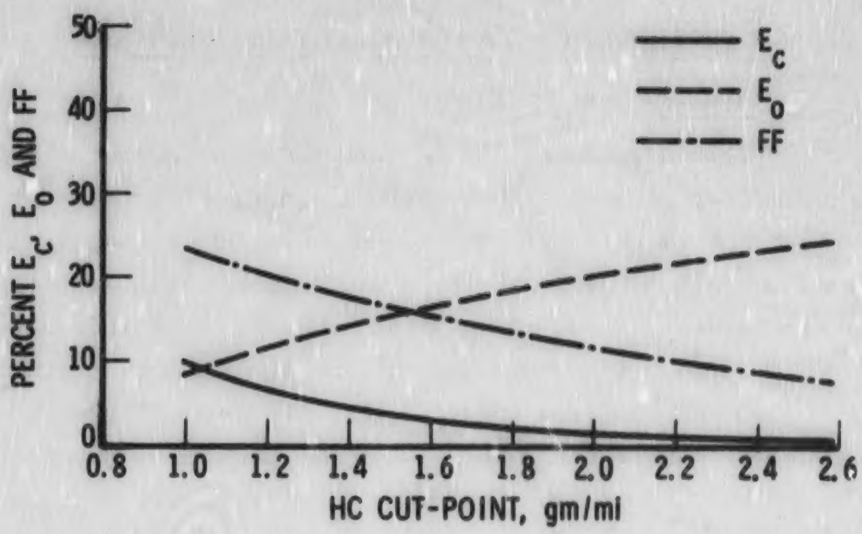

Figure 1-4. Variation of E_C, E_O, and FF with HC Cut-point; All Three Cities; Federal Short Cycle; Bounded Errors of Commission Method

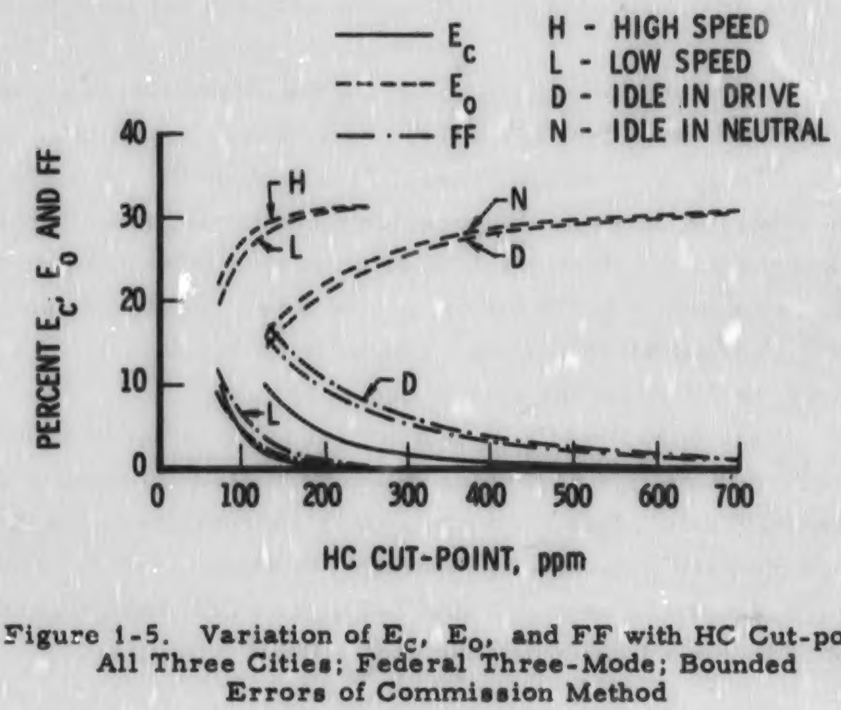

Figure 1-5. Variation of E_C, E_O, and FF with HC Cut-point; All Three Cities; Federal Three-Mode; Bounded Errors of Commission Method

Table 1-44. Comparison of Short Test HC Results for Pooled Fleet and Individual Cities; Predicted Population; Bounded Errors of Commission Method (E_c set at 5 percent)

Short Test	City	Test Mode	Number of Vehicles	Parameter, %			STE[a]	STRR[b]
				E_c	E_o	FF		
Federal Short Cycle	all		300	5.0	13.0	18.7	.589	.748
	Chicago		100	4.2	12.7	15.8	.554	.702
	Houston		100	4.0	11.4	25.5	.691	.799
	Phoenix		100	6.3	13.6	15.3	.530	.747
Federal 3-Mode	all	high	300	5.0	26.2	5.4	.172	.329
		low		5.0	24.1	7.5	.237	.396
		idle-in-drive		5.0	19.8	11.9	.375	.533
		idle-in-neutral		5.0	21.0	10.7	.338	.495
	Chicago	high	100	8.4	20.6	7.5	.266	.566
		low		6.9	19.5	8.5	.303	.550
		idle-in-drive		8.1	16.9	11.5	.405	.690
		idle-in-neutral		7.5	18.4	10.0	.352	.616
	Houston	high	100	1.3	33.7	3.3	.088	.124
		low		1.3	31.0	6.0	.162	.197
		idle-in-drive		2.2	23.6	13.3	.360	.420
		idle-in-neutral		3.2	24.1	12.8	.348	.434
	Phoenix	high	100	5.8	24.0	4.9	.171	.370
		low		7.5	21.8	7.1	.246	.505
		idle-in-drive		4.3	18.8	10.1	.349	.498
		idle-in-neutral		3.6	20.3	8.5	.296	.420

(a) Short Test Effectiveness = $\frac{\%\,FF}{\%\,FF + \%\,E_o}$

(b) Short Test Rejection Ratio = $\frac{\%\,E_c + \%\,FF}{\%\,E_o + \%\,FF}$

1.3.2 Carbon Monoxide Emission

The variation of E_c, E_o and FF for the pooled fleet as a function of CO cut-point are shown for the Federal Short Cycle and the Federal Three-Mode in Figures 1-6 and 1-7, respectively. Table 1-45 summarizes the results for both STs for the pooled fleet (300 vehicles) and the individual city fleets at the E_c analysis value of 5 percent.

In the case of the Federal Three-Mode ST, as was the case for HC emission, the idle in drive test mode is superior for CO discrimination in each city and the pooled fleet; the STE value ranges from 0.539 to 0.584 for the city fleets and is 0.562 for the pooled fleet. Again, the idle in neutral STE value is above 90 percent that of the idle in drive mode and could be substituted for those vehicles without an automatic transmission.

The STE value for the Federal Short Cycle is approximately 23 percent higher than that of the idle in drive mode; it ranges from 0.664 to 0.731 for the city fleets and is 0.690 for the pooled fleet.

With regard to the short test rejection ratio, all STRR values are below one, and relatively similar between cities and the pooled fleet.

1.3.3 Oxides of Nitrogen Emission

The variation of E_c, E_o, and FF for the pooled fleet as a function of NO_x cut points are shown in Figures 1-8 and 1-9, respectively, for the Federal Short Cycle and the Federal Three-Mode STs. Table 1-46 summarizes the results for both STs for the pooled fleet and the individual city fleets at the E_c analysis value of 5 percent.

With the Federal Three-Mode ST, as opposed to the findings for HC and CO where the idle in drive mode was superior, the high speed test mode was superior in NO_x discrimination for the pooled fleet and two of the three cities; in Houston the low speed test mode was superior (STE = 0.291 in the low speed mode and 0.249 in the high speed mode). In the other two cities the low speed mode STE value was approximately 88 percent that of the high speed mode, and in the pooled fleet it was approximately 97 percent of the high speed mode value.

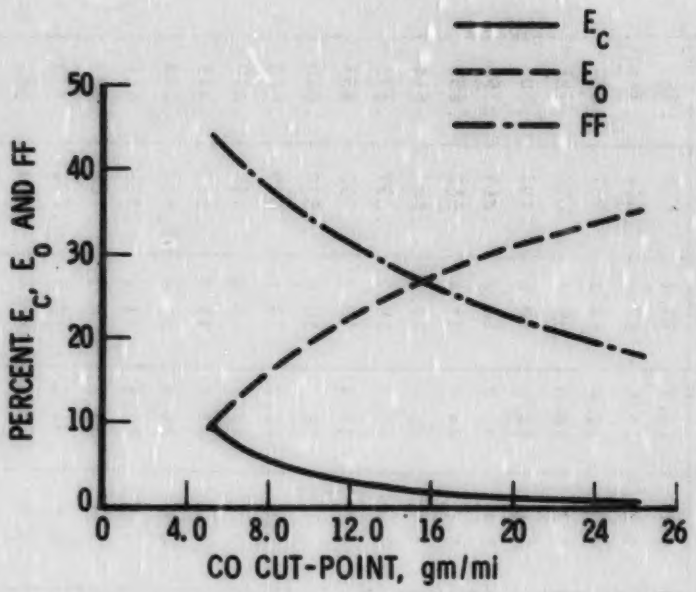

Figure 1-6. Variation of E_C, E_O, and FF with CO Cut-point; All Three Cities; Federal Short Cycle; Bounded Errors of Commission Method

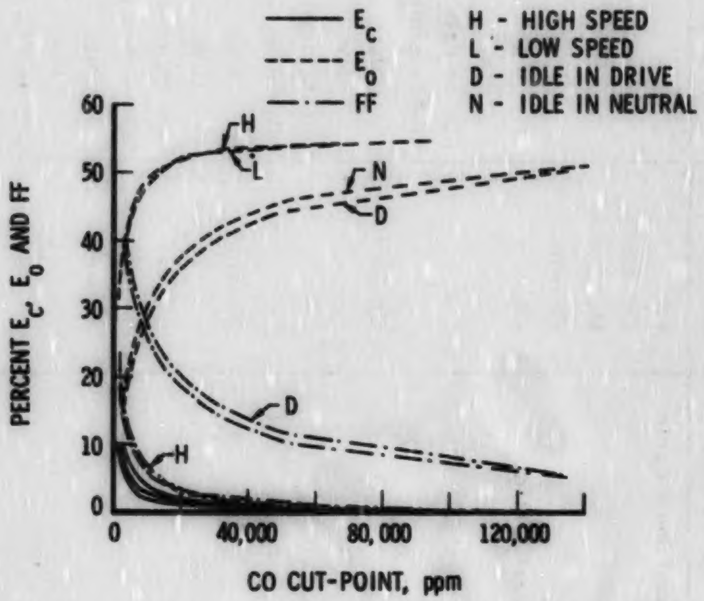

Figure 1-7. Variation of E_C, E_O, and FF with CO Cut-point; All Three Cities; Federal Three-Mode; Bounded Errors of Commission Method

Table 1-45. Comparison of Short Test CO Results for Pooled Fleet and Individual Cities; Predicted Population; Bounded Errors of Commission Method (E_c set at 5 percent)

Short Test	City	Test Mode	Number of Vehicles	Parameter, %			STE[(a)]	STRR[(b)]
				E_c	E_o	FF		
Federal Short Cycle	all		300	5.0	16.7	37.1	.690	.783
	Chicago		100	4.6	19.0	37.6	.664	.746
	Houston		100	4.1	14.4	39.1	.731	.807
	Phoenix		100	5.9	16.9	35.1	.676	.788
Federal 3-Mode	all	high	300	5.0	44.4	10.6	.193	.284
		low		5.0	40.7	14.4	.261	.352
		idle-in-drive		5.0	24.4	31.4	.562	.652
		idle-in-neutral		5.0	26.6	29.3	.524	.614
	Chicago	high	100	5.4	40.9	15.7	.277	.373
		low		5.8	37.9	18.7	.330	.433
		idle-in-drive		6.9	26.3	30.8	.539	.660
		idle-in-neutral		6.8	28.0	29.1	.509	.629
	Houston	high	100	3.7	48.6	8.2	.145	.210
		low		4.4	43.4	13.7	.239	.317
		idle-in-drive		4.5	24.5	34.4	.584	.660
		idle-in-neutral		4.5	27.5	31.7	.536	.611
	Phoenix	high	100	4.5	43.6	8.3	.160	.247
		low		3.8	41.2	10.7	.206	.279
		idle-in-drive		3.8	23.4	28.6	.551	.623
		idle-in-neutral		3.7	25.1	26.8	.517	.588

(a)Short Test Effectiveness = $\frac{\% FF}{\% FF + \% E_o}$

(b)Short Test Rejection Ratio = $\frac{\% E_c + \% FF}{\% E_o + FF}$

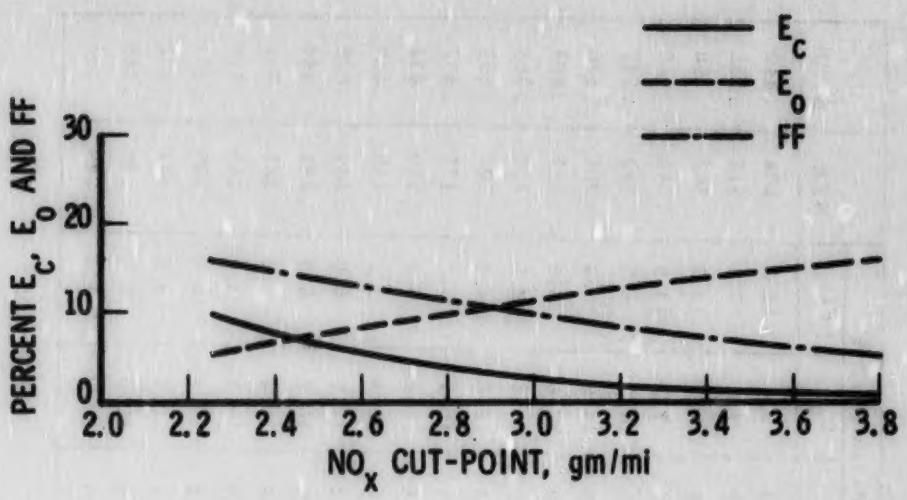

Figure 1-8. Variation of E_c, E_o, and FF with NO_x Cut-point; All Three Cities; Federal Short Cycle; Bounded Errors of Commission Method

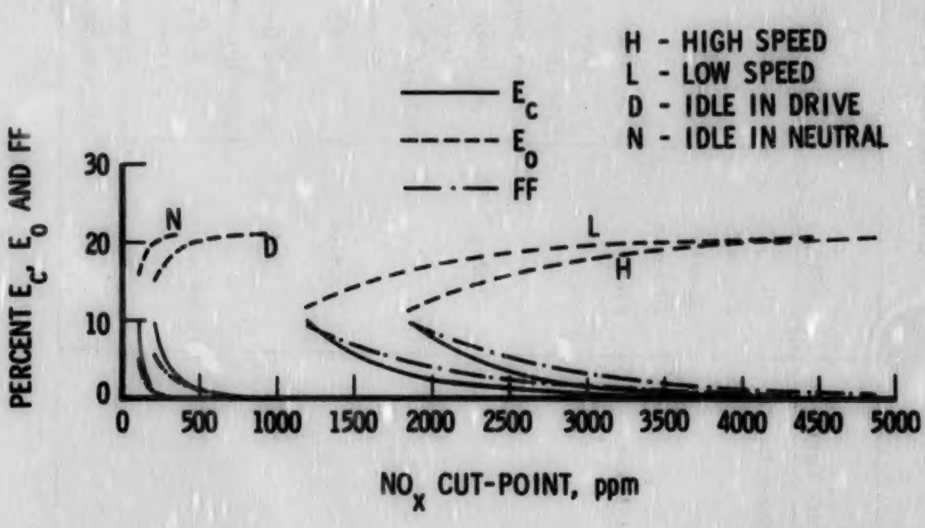

Figure 1-9. Variation of E_c, E_o, and FF with NO_x Cut-point; All Three Cities; Federal Three-Mode; Bounded Errors of Commission Method

Table 1-46. Comparison of Short Test NO_x Results for Pooled Fleet and Individual Cities; Predicted Population; Bounded Errors of Commission Method (E_c set at 5 percent)

Short Test	City	Test Mode	Number of Vehicles	Parameter, %			STE	STRR
				E_c	E_o	FF		
Federal Short Cycle	**all**		300	5.0	8.4	12.8	.604	.840
	Chicago		100	4.2	7.5	12.1	.618	.832
	Houston		100	4.4	10.3	13.3	.562	.750
	Phoenix		100	6.4	7.2	13.0	.645	.960
Federal 3-Mode	**all**	high	300	5.0	14.6	6.6	.310	.547
		low		5.0	14.8	6.4	.301	.538
		idle-in-drive		5.0	17.6	3.5	.167	.403
		idle-in-neutral		5.0	18.4	2.8	.130	.368
	Chicago	high	100	3.2	15.6	4.0	.204	.367
		low		3.1	16.1	3.5	.177	.337
		idle-in-drive		5.4	16.5	3.1	.159	.434
		idle-in-neutral		5.7	16.5	3.1	.158	.449
	Houston	high	100	4.2	17.7	5.9	.249	.428
		low		4.5	16.7	6.9	.291	.483
		idle-in-drive		3.8	18.4	5.2	.221	.381
		idle-in-neutral		4.9	19.7	3.9	.166	.373
	Phoenix	high	100	6.8	9.4	10.8	.535	.871
		low		7.1	10.7	9.5	.471	.822
		idle-in-drive		5.2	18.0	2.2	.108	.366
		idle-in-neutral		2.9	19.2	1.0	.049	.193

The STE value for NO_x in the high speed mode was quite variable with city fleet: 0.310 for the pooled fleet, 0.204 in Chicago, 0.249 in Houston, and 0.535 in Phoenix. The variation in STE value for the Federal Short Cycle was much less variable: 0.604 for the pooled fleet, 0.618 in Chicago, 0.562 in Houston, and 0.645 in Phoenix. Except for Phoenix, the Federal Short Cycle NO_x STE values were approximately double those of the Federal Three-Mode high speed test mode; in Phoenix the high speed NO_x STE value was approximately 83 percent of the Federal Short Cycle value.

In the case of short test rejection ratio, all STRR values are less than one. Phoenix, however, displays considerably higher STRR values than the other two cities (0.960 with Federal Short Cycle and 0.871 with high-speed mode of the Federal Three-Mode); this, of course, is a reflection of the higher E_c values in Phoenix as compared with Chicago and Houston.

1.3.4 Multiple-Constituent Tests

In addition to analyzing each pollutant individually, an analysis was made for three-constituent tests. In a three-constituent test, a car fails the ST if any of its HC, CO, or NO_x measurements exceed the previously determined cut-points for each pollutant.

The three-constituent test results for both STs for the pooled fleet and the individual city fleets are summarized in Table 1-47 for the E_c analysis value of 5 percent. In the case of the Federal Short Cycle ST, STE values over 0.8 were achieved in all cities and the pooled fleet.

The "best" test mode category shown for the Federal Three-Mode ST refers to the combination of best individual test modes: the idle-in-drive for HC and CO discrimination and the high-speed mode for NO_x, as was discussed in the previous sections. Although this combination of best individual test modes had relatively high STE values in all three cities (0.606 to 0.727) and in the pooled fleet (0.663), the idle-in-drive mode alone was slightly superior to this combination of modes: 0.652 in Chicago, 0.773 in Houston, 0.688 in Phoenix, and 0.704 for the pooled

Table 1-47. Comparison of Short Test Multiple Constituent Results for Pooled Fleet and Individual Cities; Actual Population; Bounded Errors of Commission Method (E_c set at 5 percent)

Short Test	City	Test Mode	Number of Vehicles	Parameter, %			STE	STRR
				E_c	E_o	FF		
Federal Short Cycle	all		300	7.0	11.7	53.7	0.821	.928
	Chicago		100	10.0	12.0	54.0	0.818	.970
	Houston		100	4.0	11.0	55.0	0.833	.894
	Phoenix		100	7.0	12.0	52.0	0.8125	.922
Federal 3-Mode	all	high	300	3.3	42.7	22.7	0.348	.398
		low		6.3	37.0	28.3	0.429	.530
		idle-in-drive		6.3	19.3	46.0	0.7044	.801
		idle-in-neutral		4.7	26.3	39.0	0.597	.669
		best[a]		4.3	22.0	43.3	0.663	.729
	Chicago	high	100	5.0	44.0	22.0	0.333	.409
		low		10.0	36.0	30.0	0.455	.606
		idle-in-drive		8.0	23.0	43.0	0.652	.773
		idle-in-neutral		7.0	28.0	38.0	0.576	.682
		best[a]		6.0	26.0	40.0	0.606	.697
	Houston	high	100	1.0	46.0	20.0	0.303	.318
		low		1.0	40.0	26.0	0.394	.409
		idle-in-drive		6.0	15.0	51.0	0.773	.864
		idle-in-neutral		3.0	24.0	42.0	0.636	.682
		best[a]		3.0	18.0	48.0	0.727	.773
	Phoenix	high	100	4.0	38.0	26.0	0.406	.469
		low		8.0	35.0	29.0	0.453	.578
		idle-in-drive		5.0	20.0	44.0	0.688	.766

(a) Best individual modes are HC in drive, CO in drive, and NO_x at high speed

Table 1-47. Comparison of Short Test Multiple Constituent Results for Pooled Fleet and Individual Cities; Actual Population; Bounded Errors of Commission Method (E_c set at 5 percent) (Continued)

Short Test	City	Test Mode	Number of Vehicles	Parameter, %			STE	STRR
				E_c	E_o	FF		
Federal 3-Mode (continued)	Phoenix (continued)	idle-in-neutral		4.0	27.0	37.0	0.578	.641
		best[(a)]		4.0	22.0	42.0	0.656	.719

[(a)] Best individual modes are HC in drive, CO in drive, and NO_x at high speed fleet. This is the result of the relatively high incidence of HC and CO FTP failures in the vehicles and the relatively low incidence of NO_x FTP failures. Thus, the inclusion of the high-speed mode, which was shown to be the superior NO_x discriminator, was relatively less effective on a three-constituent test basis than the idle-in-drive mode alone.

With regard to rejection ratio, all STRR values in Table 1-47 are below one. There is relatively little difference in STRR values between the three cities.

1.3.5 Effect of Engine Displacement

The variation of short test effectiveness and rejection ratio with engine displacement for the pooled fleet is summarized in Tables 1-48 through 1-51 for the Federal Short Cycle and the better individual test modes of the Federal Three-Mode ST.

1.3.5.1 Hydrocarbon Emission

In the case of HC (Table 1-48) on the Federal Short Cycle, the STE value of the 150 CID and less group (0.579) was essentially equivalent to the fleet average (0.589), the 151 to 259 CID group value (0.471) was 20 percent lower than the fleet average, and the 260 CID and greater group value (0.632) was 7 percent higher than the fleet average.

Using the idle-in-drive mode of the Federal Three-Mode ST, the above CID-related trends were reversed. The 150 CID and less group STE value (0.319) was 15 percent lower than the fleet average (0.375); the 151 to 259 CID group value (0.380) was essentially equivalent to the fleet average; and the 260 CID and greater group value (0.356) was 5 percent lower than the fleet average. Similar trends are observed for the idle-in-neutral test mode. The actual STE value of the idle-in-neutral mode varies from 3 percent higher than the idle-in-drive mode value with the 260 CID and greater group to 18 percent lower than the idle-in-drive mode value with the 151 to 259 CID group. For the pooled fleet, the idle-in-neutral STE value was 11 percent lower than the idle-in-drive STE value.

Table 1-48. Comparison of Short Test HC Results by Engine Displacement; All Three Cities; Predicted Population; Bounded Errors of Commission Method (E_c set at 5 percent)

Short Test	CID Group	Test Mode	Number of Vehicles	Parameter, %			STE	STRR
				E_c	E_o	FF		
Federal Short Cycle	all		300	5.0	13.0	18.7	.589	.748
	0 to 150		95	4.6	13.5	18.6	.579	.723
	151 to 259		54	4.6	14.4	12.8	.471	.640
	260 & greater		151	5.3	12.1	20.8	.632	.793
Federal 3-Mode	all	idle-in-drive	300	5.0	19.8	11.9	.375	.533
		idle-in-neutral		5.0	21.0	10.7	.338	.495
	0 to 150	idle-in-drive	95	7.1	19.6	12.6	.319	.612
		idle-in-neutral		5.7	22.7	9.4	.293	.470
	151 to 259	idle-in-drive	54	7.1	16.9	10.3	.380	.640
		idle-in-neutral		6.8	18.5	8.8	.323	.571
	260 & greater	idle-in-drive	151	3.2	21.2	11.7	.356	.453
		idle-in-neutral		4.1	20.9	12.0	.366	.489

On a comparative basis, the Federal Three-Mode STE value (idle in drive) was 36 percent lower than the Federal Short Cycle for the pooled fleet.

All rejection ratio (STRR) values in the table are less than one; the 260 CID and greater group has relatively lower STRR values than the other two CID groups on the Federal Three-Mode, and a relatively higher STRR value on the Federal Short Cycle.

1.3.5.2 Carbon Monoxide Emission

The results for CO are given in Table 1-49. On the Federal Short Cycle, the STE value of the 150 CID and less group (0.773) is 12 percent higher than the fleet average (0.690), the 151 to 259 CID group value (0.631) is 9 percent lower than the fleet average, and the 260 CID and greater group is 2 percent lower than the fleet average.

Somewhat similar CO trends are observed for the idle-in-drive mode of the Federal Three-Mode ST. The 150 CID and less group STE value (0.639) is 14 percent higher than the fleet average (0.562); the 151 to 259 CID group value (0.585) is 4 percent lower than the fleet average; and the 260 CID and greater group is 8 percent lower than the fleet average. The idle-in-neutral mode exhibits similar trends, except for the 151 to 259 CID group where the STE value is above the fleet average value instead of lower, as was the case of the idle-in-drive mode.

The idle-in-neutral STE values are lower than the idle-in-drive values, ranging from 4 percent lower for the 260 CID and greater group to 13 percent lower for the 151 to 259 CID group.

On a pooled fleet basis, the Federal Three-Mode ST (idle in drive) STE value was 19 percent lower than the Federal Short Cycle STE value.

With regard to short test rejection ratio, the 150 CID and less group had STRR values considerably above the other two CID groups on both STs; the STRR value slightly exceeded one (1.051) on the Federal Short Cycle.

Table 1-49. Comparison of Short Test CO Results by Engine Displacement; All Three Cities; Predicted Population; Bounded Errors of Commission Method (E_c set at 5 percent)

Short Test	CID Group	Test Mode	Number of Vehicles	Parameter, %			STE	STRR
				E_c	E_o	FF		
Federal Short Cycle	all		300	5.0	16.7	37.1	.690	.783
	0 to 150		95	12.5	10.2	34.5	.773	1.051
	151 to 259		54	2.7	20.5	35.0	.631	.679
	260 & greater		151	2.7	18.6	38.5	.674	.722
Federal 3-Mode	all	idle-in-drive	300	5.0	12.4	31.4	.562	.813
		idle-in-neutral		5.0	26.6	29.3	.524	.614
	0 to 150	idle-in-drive	95	12.5	16.2	28.6	.639	.917
		idle-in-neutral		12.1	19.0	25.8	.576	.846
	151 to 259	idle-in-drive	54	5.0	24.7	34.8	.585	.670
		idle-in-neutral		6.2	29.2	30.2	.508	.613
	260 & greater	idle-in-drive	151	1.8	28.8	31.1	.519	.549
		idle-in-neutral		1.7	30.3	29.8	.496	.524

1.3.5.3 Oxides of Nitrogen Emission

NO_x results are shown in Table 1-50. On the Federal Short Cycle, the STE value of the 150 CID and less group (0.530) is 12 percent lower than the fleet average (0.604), the 151 to 259 CID group value (0.626) is 4 percent higher than the fleet average, and the 260 CID and greater group value (0.600) is essentially the same as the fleet average.

The NO_x versus CID trends for the high-speed mode of the Federal Three-Mode ST are markedly different from those noted above for the Federal Short Cycle. The 150 CID and less group STE value (0.578) is 87 percent higher than the Federal Three-Mode fleet average value (0.310) and only 4 percent lower than the fleet average value for the Federal Short Cycle (0.604). The 151 to 259 CID group STE value (0.154) is 50 percent lower than the fleet average, and the 260 CID and greater value is 22 percent lower than the fleet average.

The low-speed mode STE values exhibit trends similar to the high-speed mode, except in the case of the 151 to 259 CID group wherein the low-speed STE (0.372) is higher than the fleet average (0.301) and higher than the high-speed test mode value (0.154).

On a pooled-fleet basis, the Federal Three-Mode ST (high-speed mode) STE value was 50 percent lower than the Federal Short Cycle STE value.

In the case of rejection ratio, the 150 CID and less group had the lowest STRR value on the Federal Short Cycle (0.729). On the Federal Three-Mode, this same group had considerably higher STRR values than the other two CID groups; the value exceeded one (1.219) in the high-speed mode.

1.3.5.4 Multiple Constituent Tests

The three-constituent test results for both STs on a CID group basis are summarized in Table 1-51. In the case of the Federal Short Cycle, the 150 CID and less group STE value (0.782) was 5 percent lower than the fleet average (0.821), the 151 to 259 CID group value (0.950)

Table 1-50. Comparison of Short Test NO_x Results by Engine Displacement; All Three Cities; Predicted Population; Bounded Errors of Commission Method (E_c set at 5 percent)

Short Test	CID Group	Test Mode	Number of Vehicles	Parameter, %			STE	STRR
				E_c	E_o	FF		
Federal Short Cycle	all		300	5.0	8.4	12.8	.604	.840
	0 to 150		95	3.1	7.3	8.2	.530	.729
	151 to 259		54	5.0	7.5	12.5	.626	.875
	260 & greater		151	6.7	9.9	14.9	.600	.871
Federal 3-Mode	all	high	300	5.0	14.6	6.6	.310	.547
		low		5.0	14.8	6.4	.301	.538
	0 to 150	high	95	9.9	6.5	9.0	.578	1.219
		low		4.7	9.2	5.0	.355	.683
	151 to 259	high	54	2.8	17.0	3.1	.154	.294
		low		3.5	12.6	7.4	.372	.545
	260 & greater	high	151	2.8	18.8	6.0	.242	.355
		low		4.6	19.7	5.1	.206	.391

Table 1-51. Comparison of Short Test Multiple Constituent Results by Engine Displacement; All Three Cities; Predicted Population; Bounded Errors of Commission Method (E_c set at 5 percent)

Short Test	CID Group	Test Mode	Number of Vehicles	Parameter, %			STE	STRR
				E_c	E_o	FF		
Federal Short Cycle	all		300	7.0	11.7	53.7	.821	.928
	0 to 150		95	8.4	12.6	45.3	.782	.927
	151 to 259		54	1.9	13.0	55.6	.950	.981
	260 & greater		151	8.0	10.6	58.3	.846	.962
Federal 3-Mode	all	idle-in-drive	300	6.3	19.3	46.0	.704	.801
		idle-in-neutral		4.7	26.3	39.0	.597	.669
		best [(a)]		4.3	22.0	43.3	.663	.714
	0 to 150	idle-in-drive	95	8.4	14.7	43.2	.746	.891
		idle-in-neutral		9.5	20.0	37.7	.655	.818
		best [(a)]		10.5	12.6	45.3	.782	.964
	151 to 259	idle-in-drive	54	9.3	18.5	50.0	.729	.866
		idle-in-neutral		5.6	33.3	35.2	.514	.596
		best[(a)]		1.8	25.9	42.6	.622	.648
	260 & greater	idle-in-drive	151	4.0	22.5	46.4	.673	.731
		idle-in-neutral		1.3	27.8	41.0	.596	.615
		best[(a)]		1.3	26.5	42.4	.615	.634

[(a)] Best Individual Modes are HC in Drive, CO in Drive and NO_x at High Speed was 16 percent higher than the fleet average, and the 260 CID and greater group STE value (0.846) was 3 percent higher than the fleet average.

In the case of the Federal Three-Mode, only the idle and best (best combination of individual test modes: HC in drive, CO in drive, and NO_x in high speed) modes are shown, because the high and low speed modes displayed markedly inferior discrimination capability on a three-constituent basis (see Table 1-47, for example). The idle-in-drive mode is the superior test mode in all cases except the 150 CID and less group, wherein the best mode STE value (0.782) was 5 percent higher than the idle-in-drive mode. Although the idle-in-neutral test mode produced lower STE values than the idle-in-drive mode (from 12 to 30 percent lower), it would be applicable to cars with standard transmissions.

The CID-related trends of the idle-in-drive test mode (and best combination, as well) were not the same as exhibited by the Federal Short Cycle. The 150 CID and less group STE value (0.746) was 6 percent higher than the fleet average (0.704); the 151 to 259 CID group value (0.729) was 4 percent higher than the fleet average; and the 260 CID and greater group value (0.673) was 4 percent lower than the fleet average.

With regard to rejection ratio, all STRR values were below one, as shown in Table 1-51. There is little discernible difference between the CID groups on the Federal Short Cycle; on the Federal Three-Mode ST, the 150 CID and less group has the highest STRR values.

1.3.6 Effect of Inertia Test Weight Group

The variation of short test effectiveness and rejection ratio with vehicle inertia test weight group is summarized in Tables 1-52 through 1-55 for the Federal Short Cycle and the better individual test modes of the Federal Three-Mode ST.

1.3.6.1 Hydrocarbon Emission

In the case of HC (Table 1-52) on the Federal Short Cycle, the STE value of the 2500-lb and less weight group (0.431) is 27 percent lower than the fleet average (0.589), the 2501-lb to 3500-lb weight group STE value (0.606) is 3 percent higher than the fleet average, the 3501-lb to 4500-lb weight group STE value is the highest (0.667, 13 percent above the fleet average), and the 4501-lb and greater weight group has an STE value (0.575) which is 2 percent below the fleet average.

With the idle-in-drive mode of the Federal Three-Mode ST, the above noted trends for three of the four weight groups are similar. The 2500-lb and less weight group STE value (0.293) is 22 percent lower than the fleet average (0.375); the 2501-lb to 3500-lb weight group STE value (0.439) is 17 percent higher than the fleet average; the 3501-lb to 4500-lb weight group STE value (0.340) is 9 percent below the fleet average (it was 13 percent higher than fleet average on the Federal Short Cycle); and the 4501-lb and greater weight group has an STE value (0.385) which is 3 percent higher than the fleet average (it was 2 percent below the average on the Federal Short Cycle).

Trends for the idle-in-neutral test mode are similar to those noted above for the idle-in-drive test mode. For the pooled fleet, the idle-in-neutral STE value (0.338) was 10 percent lower than the idle-in-drive STE value (0.375).

On a comparative basis, the Federal Three-Mode ST (idle-in-drive mode) was 36 percent lower in STE value than the Federal Short Cycle, for the pooled fleet.

All inertia weight groups had STRR values less than one on both STs, with little discernible weight-related trend information.

Table 1-52. Comparison of Short Test HC Results by Inertia Weight; All Three Cities; Bounded Errors of Commission Method; Predicted Population (E_c set at 5 percent)

Short Test	Inertia Weight	Test Mode	Number of Vehicles	Parameter, % E_c	E_o	FF	STE	STRR
Federal Short Cycle	all		300	5.0	13.0	18.7	.589	.748
	0 to 2500		50	3.5	19.0	14.4	.431	.536
	2501 to 3500		119	4.5	11.4	17.6	.606	.567
	3501 to 4500		98	4.5	9.3	18.7	.667	.829
	4501 & greater		33	8.3	21.1	28.6	.575	.742
Federal 3-Mode	all	idle-in-drive	300	5.0	19.8	11.9	.375	.533
		idle-in-neutral		5.0	21.0	10.7	.338	.495
	0 to 2500	idle-in-drive	50	4.4	24.0	9.8	.293	.420
		idle-in-neutral		4.2	25.0	8.9	.265	.386
	2501 to 3500	idle-in-drive	119	6.6	16.3	12.7	.439	.666
		idle-in-neutral		5.5	19.0	10.0	.344	.534
	3501 to 4500	idle-in-drive	98	4.2	18.5	9.5	.340	.489
		idle-in-neutral		5.0	18.7	9.3	.333	.511
	4501 & greater	idle-in-drive	33	2.3	30.6	19.1	.385	.431
		idle-in-neutral		3.9	29.4	20.3	.408	.487

1.3.6.2 Carbon Monoxide Emission

The results for CO are given in Table 1-53. On the Federal Short Cycle, the STE value of the 2500-lb and less weight group (0.715) is 4 percent higher than the fleet average (0.690), the 2501-lb to 3500-lb weight group STE value (0.663) is 4 percent lower than the fleet average, the 3501-lb to 4500-lb weight group value (0.718) is 4 percent higher than the fleet average, and the 4501-lb and greater weight group has an STE value (0.705) that is 2 percent higher than the fleet average. All weight groups are similar in STE value (0.705 to 0.718) except the 2501-lb to 3500-lb group, whose STE value (0.663) is 7 percent below the average of the other three weight groups.

Somewhat different trends are observed for the idle-in-drive mode of the Federal Three-Mode ST. Here, the STE values of the 2500-lb and less weight group (0.583) and the 2501-lb to 3500-lb group (0.617) are above the fleet average (0.562) by 4 and 10 percent, respectively; the STE values of the two heavier weight groups (0.553 for 3501 lb to 4500 lb; 0.509 for 4501 lb and greater) are 5 and 10 percent lower than the fleet average, respectively. The idle-in-neutral mode exhibits similar trends except for the 4501-lb and greater weight group which recorded the highest STE value obtained (0.838) by either the Federal Short Cycle or the Federal Three-Mode.

The idle-in-neutral STE values were lower than the idle-in-drive values (6 to 10 percent lower) except for the 4501-lb and greatest group, as noted above, which was 65 percent higher than the idle-in-drive value.

On a pooled-fleet basis, the Federal Three-Mode ST (idle in drive), STE value was 19 percent lower than the Federal Short Cycle STE value.

With regard to rejection ratio, the higher E_c values of the 2500-lb and less group result in STRR values considerably higher than the other weight groups for both STs. On the Federal Short Cycle, the STRR value of this group exceeds one (1.064).

Table 1-53. Comparison of Short Test CO Results by Inertia Weight; All Three Cities; Bounded Errors of Commission Method: Predicted Population (E_c set at 5 percent)

Short Test	Inertia Weight	Test Mode	Number of Vehicles	Parameter, %			STE	STRR
				E_c	E_o	FF		
Federal Short Cycle	all		300	5.0	16.7	37.1	.690	.783
	0 to 2500		50	13.1	10.7	26.9	.715	1.064
	2501 to 3500		119	4.6	16.5	32.6	.663	.758
	3501 to 4500		98	3.1	16.0	40.8	.718	.773
	4501 & greater		33	2.3	22.3	53.1	.705	.735
Federal 3-Mode	all	idle-in-drive	300	5.0	24.4	31.4	.562	.652
		idle-in-neutral		5.0	26.6	29.3	.524	.614
	0 to 2500	idle-in-drive	50	14.6	15.8	22.0	.583	.968
		idle-in-neutral		14.5	17.8	20.0	.528	.913
	2501 to 3500	idle-in-drive	119	5.6	19.3	31.0	.617	.728
		idle-in-neutral		5.8	22.4	28.2	.557	.672
	3501 to 4500	idle-in-drive	98	2.0	27.9	31.8	.533	.566
		idle-in-neutral		1.6	30.0	30.1	.500	.527
	4501 & greater	idle-in-drive	33	1.0	40.2	41.7	.509	.521
		idle-in-neutral		6.1	12.3	65.5	.838	.920

1.3.6.3 Oxides of Nitrogen Emission

NO_x results are shown in Table 1-54. On the Federal Short Cycle, all inertia weight groups except the 2500-lb and less group were similar in STE value (from 0.585 to 0.618) and corresponded well with the fleet average STE (0.604). The smallest weight group had a very low STE value of 0.251, 68 percent lower than the fleet average.

The high-speed mode of the Federal Three-Mode shows quite different results. Here, the smallest weight group (2500 lb and less) has the highest STE value (0.552); the 2501-lb to 3500-lb group value (0.315) is near the fleet average (0.310); and the two largest weight groups have increasingly poorer STE values (0.214 and 0.114, respectively).

The low-speed mode results show the 2501-lb to 3500-lb group with the highest STE value (0.417), with the other three groups lower than the fleet average value of 0.301. Although essentially the same in STE value for the pooled fleet as the high-speed mode, the low-speed mode more closely agrees with the Federal Short Cycle with regard to the effect of the smallest inertia test weight group.

On a pooled-fleet basis, the Federal Three-Mode (high-speed mode) STE value was 49 percent lower than the Federal Short Cycle value. This is largely due to the relatively low STE values obtained for the two largest inertia test weight groups.

With the Federal Short Cycle, all STRR values are less than one, and the 2500-lb and less weight group has an STRR value less than half that of the other weight groups. This situation is reversed with the Federal Three-Mode. Here, the STRR value is 3.0 for the 2500 lb and less group on the high-speed mode and just under one (0.981) on the low-speed mode.

1.3.6.4 Multiple Constituent Tests

The three-constituent test results for both STs on an inertia test weight basis are summarized in Table 1-55. In the case of the Federal

Table 1-54. Comparison of Short Test NO_x Results by Inertia Weight; All Three Cities; Bounded Errors of Commission Method; Predicted Population (E_c set at 5 percent)

Short Test	Inertia Weight	Test Mode	Number of Vehicles	Parameter, %			STE	STRR
				E_c	E_o	FF		
Federal Short Cycle	all		300	5.0	8.4	12.8	.604	.840
	0 to 2500		50	0.8	4.0	1.3	.251	.396
	2501 to 3500		119	4.5	9.1	14.7	.618	.807
	3501 to 4500		98	5.9	9.5	14.3	.602	.849
	4501 & greater		33	5.1	7.8	11.0	.585	.856
Federal 3-Mode	all	high	300	5.0	14.6	6.6	.310	.547
		low		5.0	14.8	6.4	.301	.538
	0 to 2500	high	50	13.2	2.4	3.0	.552	3.00
		low		3.9	4.0	1.3	.250	.981
	2501 to 3500	high	119	4.2	16.3	7.5	.315	.492
		low		5.4	13.9	10.0	.417	.644
	3501 to 4500	high	98	2.6	18.7	5.1	.214	.324
		low		3.9	19.3	4.6	.191	.356
	4501 & greater	high	33	1.3	16.6	2.1	.114	.182
		low		1.6	17.0	1.8	.095	.182

Table 1-55. Comparison of Multiple Constituent Results by Inertia Weight; All Three Cities; Bounded Errors of Commission Method; Actual Population (E_c set at 5 percent)

Short Test	Inertia Weight	Test Mode	Number of Vehicles	Parameter, %			STE	STRR
				E_c	E_o	FF		
Federal Short Cycle	all		300	7.0	11.7	53.7	.821	.928
	0 to 2500		50	10.0	6.0	40.0	.870	1.087
	2501 to 3500		119	6.7	16.0	49.6	.756	.858
	3501 to 4500		98	6.1	10.2	60.2	.855	.942
	4501 & greater		33	6.1	9.1	69.7	.885	.962
Federal 3-Mode	all	idle-in-drive	300	6.3	19.3	46.0	.704	.801
		idle-in-neutral		4.7	26.3	39.0	.597	.669
		best[a]		4.3	22.0	43.3	.663	.714
	0 to 2500	idle-in-drive	50	10.0	14.0	32.0	.696	.913
		idle-in-neutral		12.0	14.0	32.0	.696	.957
		best[a]		12.0	12.0	34.0	.739	1.00
	2501 to 3500	idle-in-drive	119	7.6	15.0	50.4	.771	.887
		idle-in-neutral		5.0	26.0	40.0	.606	.682
		best[a]		4.2	17.6	48.0	.732	.796
	3501 to 4500	idle-in-drive	98	5.1	25.5	44.9	.637	.710
		idle-in-neutral		2.0	33.7	36.7	.521	.550
		best[a]		2.0	30.6	39.8	.565	.594
	4501 & greater	idle-in-drive	33	0.0	24.2	54.6	.693	.693
		idle-in-neutral		0.0	24.2	54.5	.692	.692
		best[a]		0.0	27.2	51.5	.654	.654

[a] Best individual modes are HC in drive, CO in drive, and NO_x at high speed.

Short Cycle, all weight groups had STE values of the same approximate level (0.756 to 0.885), compared with the fleet average value of 0.821. The 2501-lb to 3500-lb weight group had the lowest value, which was only 8 percent below the fleet average.

In the case of the Federal Three-Mode, only the idle and best combination of individual test modes are shown. The idle-in-drive test mode is the superior test mode in all cases except the 2500-lb and less weight group, where the best mode STE value (0.739) was 6 percent higher than the idle-in-drive value. The idle-in-neutral test mode values were the same as the idle-in-drive values for the 2500-lb and less and 4501-lb and greater weight groups; for the other two weight groups, the idle-in-neutral STE values were approximately 20 percent lower than the idle-in-drive values.

Whereas the 2501-lb to 3500-lb weight group had the lowest STE value (0.756) on the Federal Short Cycle, it had the highest STE value on the idle-in-drive test mode (0.771) and nearly the highest value (0.732) with the best combination test mode.

All STRR values are relatively high on the Federal Short Cycle; the 2500-lb and less weight group is the highest in STRR value (1.087). This weight group also has the highest STRR values on the Federal Three-Mode, reaching 1.0 with the combination of best individual test modes.

1.3.7 Effect of Emission Control System Type

The variation of short test effectiveness and rejection ratio with emission control system type is summarized in Tables 1-56 through 1-59 for the Federal Short Cycle and the better individual test modes of the Federal Three-Mode ST.

1.3.7.1 Hydrocarbon Emission

As shown in Table 1-56, on the Federal Short Cycle the use or non-use of oxidation catalysts and/or secondary air injection for HC

Table 1-56. Comparison of Short Test HC Results by Emission Controls; All Three Cities; Predicted Population; Bounded Errors of Commission Method (E_c set at 5 percent)

Short Test	Emission Controls	Test Mode	Number of Vehicles	Parameter, %			STE	STRR
	Catalyst/2nd Air			E_c	E_o	FF		
Federal Short Cycle	all		300	5.0	13.0	18.7	.589	.748
	yes/yes		89	3.2	8.6	11.4	.570	.730
	yes/no		127	4.5	14.7	22.3	.602	.724
	no/yes		59	7.5	10.7	18.9	.639	.892
	no/no		25	4.7	34.0	20.4	.376	.461
Federal 3-Mode	all	idle-in-drive	300	5.0	19.8	11.9	.375	.533
		idle-in-neutral		5.0	21.0	10.7	.338	.495
	yes/yes	idle-in-drive	89	3.5	17.0	3.0	.149	.325
		idle-in-neutral		3.5	17.2	2.7	.136	.312
	yes/no	idle-in-drive	127	4.6	18.3	18.6	.504	.629
		idle-in-neutral		5.5	18.6	18.4	.498	.646
	no/yes	idle-in-drive	59	5.4	20.1	9.5	.321	.503
		idle-in-neutral		3.5	24.5	5.1	.172	.291
	no/no	idle-in-drive	25	6.8	35.3	19.1	.352	.476
		idle-in-neutral		5.3	37.2	17.2	.316	.432

control produces no discernible trends except that those vehicles which did not have either a catalyst or secondary air injection ("no/no") had a definitely lower STE value (0.376), which was 36 percent lower than the fleet average.

Using the idle-in-drive mode of the Federal Three-Mode ST, the above trend is not seen. Indeed, the no/no STE value (0.352) is second only to the "yes/no" category (0.504). With both a catalyst and secondary air ("yes/yes"), the STE value is quite low (0.149).

The idle-in-neutral results parallel those of the idle-in-drive test mode; on a fleet average basis, the neutral mode STE value is 10 percent lower than the drive mode STE value.

All STRR values were below one, with no readily discernible trends by control system type.

1.3.7.2 Carbon Monoxide Emission

The results for CO are given in Table 1-57. With the Federal Short Cycle ST, there appear to be no readily observed trends attendant to the use or non-use of catalysts and/or secondary air. However, the yes/yes category does have the lowest STE value (0.642, 7 percent below the fleet average).

With the idle-in-drive mode of the Federal Three-Mode ST, the yes/yes category again has the lowest STE value (0.478, 15 percent below the fleet average). The idle-in-neutral test mode results closely parallel the idle-in-drive findings; on a fleet average basis, the neutral mode is 7 percent lower in STE value than the drive mode.

With regard to rejection ratio, all groups were similar except for the "no/yes" category. This group had an STRR value in excess of one (1.234) on the Federal Short Cycle and STRR values of 0.964 and 1.029 for the idle-in-drive and neutral test modes, respectively. These STRR values reflect the high E_c values for this control combination.

Table 1-57. Comparison of Short Test CO Results by Emission Controls; All Three Cities; Predicted Population; Bounded Errors of Commission Method (E_c set at 5 percent)

Short Test	Emission Controls	Test Mode	Number of Vehicles	Parameter, %			STE	STRR
	Catalyst/2nd. Air			E_c	E_o	FF		
Federal Short Cycle	all		300	5.0	16.7	37.1	.690	.783
	yes/yes		89	4.8	14.3	25.6	.642	.762
	yes/no		127	2.1	20.0	46.7	.700	.732
	no/yes		59	17.0	7.3	34.1	.823	1.234
	no/no		25	8.1	15.1	33.8	.691	.857
Federal 3-Mode	all	idle-in-drive	300	5.0	12.4	31.4	.562	.831
		idle-in-neutral		5.0	26.6	29.3	.524	.614
	yes/yes	idle-in-drive	89	2.5	22.0	20.1	.478	.537
		idle-in-neutral		2.5	24.2	18.0	.425	.486
	yes/no	idle-in-drive	127	2.8	30.1	39.3	.566	.607
		idle-in-neutral		3.2	32.0	37.9	.543	.588
	no/yes	idle-in-drive	59	15.0	16.5	25.0	.602	.964
		idle-in-neutral		13.3	22.1	19.3	.467	1.029
	no/no	idle-in-drive	25	10.7	13.6	35.2	.721	.941
		idle-in-neutral		9.2	13.3	35.4	.725	.916

Although less than one in STRR value, the no/no group was also high on the Federal Three-Mode with values of 0.941 and 0.916 on the idle-in-drive and neutral test modes.

1.3.7.3 Oxides of Nitrogen Emission

NO_x results are shown in Table 1-58. On the Federal Short Cycle ST, the no/yes category has the lowest departure from the fleet average STE value of 0.604, being 14 percent lower at STE = 0.522, whereas the no/no category (0.696) is 15 percent higher than the fleet average. The yes/yes category is within 4 percent of the fleet average, and the yes/no category is essentially equivalent to the fleet average.

Using the high-speed mode of the Federal Three-Mode, the above trends are reversed. The no/no category (0.188) is 40 percent lower than the fleet average STE value (0.310), and the no/yes category (0.495) is 60 percent higher than the fleet average. Similar trends are also shown with the low-speed test mode.

With regard to rejection ratio, the yes/no category exceeded one in STRR value (1.057) on the Federal Short Cycle, and the no/no category exceeded one (1.151) on the high-speed mode of the Federal Three-Mode.

1.3.7.4 Multiple Constituent Tests

The three-constituent test results for both STs on an emission control system basis are summarized in Table 1-59. In the case of the Federal Short Cycle, the most notable effects are the yes/yes category STE value of 0.764 (7 percent below the fleet average of 0.821) and the no/no category STE value of 0.933 (14 percent above the fleet average).

In the case of the Federal Three-Mode ST, only the idle and best combination of individual test modes are shown. The idle-in-drive test mode indicates that the yes/yes category has the lowest STE value (0.471, 33 percent below the fleet average of 0.704); the other categories all have rather high STE values (0.703 to 0.817, which approach the STE

Table 1-58. Comparison of Short Test NO_x Results by Emission Controls; All Three Cities; Predicted Population; Bounded Errors of Commission Method (E_c set at 5 percent)

Short Test	Emission Controls Catalyst/2nd. Air	Test Mode	Number of Vehicles	Parameter, % E_c	Parameter, % E_o	Parameter, % FF	STE	STRR
Federal Short Cycle	all		300	5.0	8.4	12.8	.604	.840
	yes/yes		89	3.8	14.8	20.6	.582	.689
	yes/no		127	7.2	6.3	9.6	.602	1.057
	no/yes		59	1.4	8.8	9.6	.522	.598
	no/no		25	3.9	4.2	9.7	.696	.978
Federal 3-Mode	all	high	300	5.0	14.6	6.6	.310	.547
		low		5.0	14.8	6.4	.301	.538
	yes/yes	high	89	1.9	21.8	8.6	.283	.345
		low		1.3	25.6	4.8	.158	.201
	yes/no	high	127	5.4	11.5	4.4	.279	.616
		low		8.1	9.6	6.3	.395	.906
	no/yes	high	59	6.6	9.3	9.1	.495	.853
		low		3.6	10.0	8.3	.451	.650
	no/no	high	25	12.9	11.3	2.6	.188	1.151
		low		6.2	10.5	3.4	.244	.691

Table 1-59. Comparison of Short Test Multiple Constituent Results by Emission Controls; All Three Cities; Predicted Population; Bounded Errors of Commission Method (E_c set at 5 percent)

Short Test	Emission Controls	Test Mode	Number of Vehicles	Parameter, %			STE	STRR
	Catalyst/2nd. Air			E_c	E_o	FF		
Federal Short Cycle	all		300	7.0	11.7	53.7	.821	.928
	yes/yes		89	10.1	13.5	43.8	.764	.941
	yes/no		127	3.9	13.4	59.8	.816	.870
	no/yes		59	5.1	8.5	54.2	.864	.946
	no/no		25	11.0	4.0	56.0	.933	1.120
Federal 3-Mode	all	idle-in-drive	300	6.3	19.3	46.0	.704	.801
		idle-in-neutral		4.7	26.3	39.0	.597	.669
		best[a]		4.3	22.0	43.3	.663	.729
	yes/yes	idle-in-drive	89	3.4	30.3	27.0	.471	.531
		idle-in-neutral		1.1	36.0	21.3	.372	.391
		best[a]		3.4	30.3	27.0	.471	.531
	yes/no	idle-in-drive	127	6.3	13.4	59.8	.817	.903
		idle-in-neutral		3.9	19.7	53.5	.731	.784
		best[a]		2.4	18.9	54.3	.742	.775
	no/yes	idle-in-drive	59	8.5	18.6	44.1	.703	.839
		idle-in-neutral		6.8	30.5	32.2	.514	.622
		best[a]		8.5	20.3	42.4	.676	.812
	no/no	idle-in-drive	25	12.0	12.0	48.0	.800	1.00

[a] Best individual modes are HC in drive, CO in drive, and NO_x at high speed.

value range of the Federal Short Cycle). The idle-in-neutral and best combination test modes follow the idle-in-drive trends at a slightly lower STE value.

All STRR values were less than one, except for the no/no category. On the Federal Short Cycle, the STRR value was 1.20 and on the idle-in-drive mode of the Federal Three-Mode it was 1.0.

1.3.8 Effect of Carburetion vs Fuel Injection

The variation of short test effectiveness and rejection ratio with fuel system type is summarized in Tables 1-60 through 1-63 for the Federal Short Cycle and the better individual test modes of the Federal Three-Mode ST.

1.3.8.1 Hydrocarbon Emission

In the case of HC (Table 1-60) on the Federal Short Cycle, the carbureted vehicles achieved an STE value (0.600) 20 percent higher than the STE value of the fuel injected vehicles (0.501).

Using the idle in drive test mode of the Federal Three-Mode, however, the roles are reversed and the fuel-injected vehicles had an STE value (0.401) 8 percent higher than that of the carbureted vehicles (0.370). The idle in neutral results paralleled the idle in drive results.

All STRR values were less than one, with no evident trends by fuel system type.

1.3.8.2 Carbon Monoxide Emission

The results for CO are given in Table 1-61. On the Federal Short Cycle, the fuel injected vehicles achieved a 27 percent higher STE value (0.868) than the carbureted vehicle STE value (0.682).

In the idle in drive test mode of the Federal Three-Mode ST, the fuel injected vehicles again had a higher STE value (0.781), with a 70 percent increase over the carbureted value (0.458). The idle in neutral results were similar.

Table 1-60. Comparison of Short Test HC Results by Fuel System Type; All Three Cities; Predicted Population; Bounded Errors of Commission Method (E_c set at 5 percent)

Short Test	Fuel System	Test Mode	Number of Vehicles	Parameter, %			STE	STRR
				E_c	E_o	FF		
Federal Short Cycle	all		300	5.0	13.0	18.7	.589	.748
	injection		30	3.3	20.7	20.7	.501	.580
	carburetion		270	5.2	12.3	18.4	.600	.769
Federal 3-Mode	all	idle-in-drive	300	5.0	19.8	11.9	.375	.533
		idle-in-neutral		5.0	21.0	10.7	.338	.495
	injection	idle-in-drive	30	7.0	24.8	16.6	.401	.570
		idle-in-neutral		6.2	26.5	14.9	.360	.510
	carburetion	idle-in-drive	270	4.8	19.3	11.3	.370	.526
		idle-in-neutral		4.9	20.4	10.2	.334	.493

Table 1-61. Comparison of Short Test CO Results by Fuel System Type; All Three Cities; Predicted Population; Bounded Errors of Commission Method (E_c set at 5 percent)

Short Test	Fuel System	Test Mode	Number of Vehicles	Parameter, %			STE	STRR
				E_c	E_o	FF		
Federal Short Cycle	all		300	5.0	16.7	37.1	.690	.783
	injection		30	8.9	5.8	38.1	.868	1.071
	carburetion		270	4.4	17.4	37.3	.682	.762
Federal 3-Mode	all	idle-in-drive	300	5.0	24.4	31.4	.562	.652
		idle-in-neutral		5.0	26.6	29.3	.524	.614
	injection	idle-in-drive	30	13.2	9.6	34.3	.781	1.082
		idle-in-neutral		10.7	12.0	32.0	.728	.971
	carburetion	idle-in-drive	270	4.1	25.8	31.2	.547	.602
		idle-in-neutral		4.3	28.0	29.2	.511	.586

With regard to rejection rate, the fuel-injected vehicles had much higher STRR values than the carbureted vehicles, because of higher E_c values. On the Federal Short Cycle the fuel-injected STRR value was 1.071, and on the Federal Short Cycle (idle-in-drive mode) it was 1.082.

1.3.8.3 Oxides of Nitrogen Emission

NO_x results are shown in Table 1-62. On the Federal Short Cycle, the fuel-injected vehicles had a very low STE value (0.201); the carbureted vehicle STE value (0.629) was over three times higher.

This pattern is reversed using the high-speed mode of the Federal Three-Mode ST, where the fuel injected STE value (0.426) is 42 percent higher than the carbureted value (0.301). When the low-speed test mode is used, the situation reverses again, and the carbureted vehicles then have 13 percent higher STE value.

As in the case of CO noted above, the fuel-injected vehicles had a considerably higher STRR value (1.480) on the Federal Three-Mode. On the Federal Short Cycle, however, the fuel-injected vehicles were lower in STRR value (0.494) than the carbureted vehicles (0.854).

1.3.8.4 Multiple Constituent Tests

The three-constituent test results on a fuel system basis are summarized in Table 1-63. On the Federal Short Cycle, the fuel injected vehicles had an STE value (0.876) 7 percent higher than the carbureted vehicles (0.816). This parallels the finding for CO alone, as noted above, because CO was the principal pollutant causing the majority of FTP failures observed in the 300-car test fleet.

Using the idle in drive, idle in neutral, or best combination of test modes, in all cases the fuel injected vehicles had higher STE values than the carbureted vehicles. For example, with the idle in drive mode, the fuel injected STE value (0.812) was 17 percent higher than the carbureted STE value (0.694).

Table 1-62. Comparison of Short Test NO_x Results by Fuel System Type; All Three Cities; Predicted Population; Bounded Errors of Commission Method (E_c set at 5 percent)

Short Test	Fuel System	Test Mode	Number of Vehicles	Parameter, %			STE	STRR
				E_c	E_o	FF		
Federal Short Cycle	all		300	5.0	8.4	12.8	.604	.840
	injection		30	2.2	6.1	1.6	.201	.494
	carburetion		270	5.1	8.4	14.2	.629	.854
Federal 3-Mode	all	high	300	5.0	14.6	6.6	.310	.547
		low		5.0	14.8	6.4	.301	.538
	injection	high	30	5.3	2.9	2.1	.426	1.480
		low		6.9	5.6	2.1	.271	1.169
	carburetion	high	270	4.6	15.7	6.8	.301	.507
		low		4.8	15.7	6.9	.305	.518

Table 1-63. Comparison of Short Test Multiple Constituent Results by Fuel System Type; All Three Cities; Predicted Population; Bounded Errors of Commission Method (E_c set at 5 percent)

Short Test	Fuel System	Test Mode	Number of Vehicles	Parameter, %			STE	STRR
				E_c	E_o	FF		
Federal Short Cycle	all		300	7.0	11.7	53.7	.821	.928
	injection		30	10.0	6.7	46.7	.876	1.062
	carburetion		270	6.7	12.2	54.4	.816	.917
Federal 3-Mode	all	idle-in-drive	300	6.3	19.3	46.0	.704	.801
		idle-in-neutral		4.7	26.3	39.0	.597	.669
		best[(a)]		4.3	22.0	43.3	.663	.729
	injection	idle-in-drive	30	13.3	10.0	43.3	.812	1.062
		idle-in-neutral		16.7	13.3	40.0	.751	1.064
		best[(a)]		13.3	6.7	46.7	.875	1.124
	carburetion	idle-in-drive	270	5.6	20.4	46.3	.694	.778
		idle-in-neutral		3.3	27.8	38.9	.583	.633
		best[(a)]		3.3	23.7	43.0	.645	.694

[(a)] Best individual modes are HC in drive, CO in drive, and NO_x at high speed.

With regard to rejection ratio, the fuel-injected vehicles had higher STRR values than the carbureted vehicles on both STs, and exceeded one in both cases.

1.3.9 Effect of Transmission Type

The variation of short test effectiveness and rejection ratio with transmission type is summarized in Tables 1-64 through 1-67 for the Federal Short Cycle and the better individual test modes of the Federal Three-Mode ST.

1.3.9.1 Hydrocarbon Emission

As shown in Table 1-64, on the Federal Short Cycle, the vehicles with automatic transmissions achieved an STE value (0.674) which was 40 percent higher than that achieved by vehicles with manual transmissions (0.481).

With the idle in drive mode of the Federal Three-Mode ST, the above pattern remained unchanged; the automatic case received an STE value (0.401) 35 percent higher than the manual case (0.296). These same trends were shown by the idle in neutral test mode, however the margin of difference was reduced from 35 to 16 percent.

All STRR values were less than one and of the same relative level for both transmission types.

1.3.9.2 Carbon Monoxide Emission

The results for CO are shown in Table 1-65. On the Federal Short Cycle, the vehicles with manual transmissions resulted in a STE value of 0.752, 11 percent higher than the STE value (0.678) for automatic transmissions.

This same relationship held on the idle in neutral mode of the Federal Three-Mode ST (0.578 versus 0.512), although the difference increased from 11 percent to 13 percent. Comparisons on the idle in drive mode cannot be made because the vehicles with manual transmissions could not be tested in this mode.

Table 1-64. Comparison of Short Test HC Results by Transmission Type; All Three Cities; Predicted Population; Bounded Errors of Commission Method (E_c set at 5 percent)

Short Test	Transmission Type	Test Mode	Number of Vehicles	Parameter, %			STE	STRR
				E_c	E_o	FF		
Federal Short Cycle	all		300	5.0	13.0	18.7	.589	.748
	automatic		229	5.1	11.4	19.0	.624	.793
	manual		71	4.8	18.9	17.4	.481	.639
Federal 3-Mode	all	idle-in-drive	300	5.0	19.8	11.9	.375	.533
		idle-in-neutral		5.0	21.0	10.7	.338	.495
	automatic	idle-in-drive	229	4.9	18.2	12.2	.401	.563
		idle-in-neutral		4.9	19.8	10.6	.348	.510
	manual	idle-in-drive	71	5.4	25.6	10.7	.296	.444
		idle-in-neutral		5.6	25.3	10.9	.301	.456

Table 1-65. Comparison of Short Test CO Results by Transmission Type; All Three Cities; Predicted Population; Bounded Errors of Commission Method (E_c set at 5 percent)

Short Test	Transmission Type	Test Mode	Number of Vehicles	Parameter, %			STE	STRR
				E_c	E_o	FF		
Federal Short Cycle	all		300	5.0	16.7	37.1	.690	.783
	automatic		229	3.4	18.1	38.0	.678	.738
	manual		71	12.2	10.8	32.8	.752	1.032
Federal 3-Mode	all	idle-in-drive	300	5.0	24.4	31.4	.562	.652
		idle-in-neutral		5.0	26.6	29.3	.524	.614
	automatic	idle-in-drive	229	3.6	26.1	32.7	.556	.617
		idle-in-neutral		3.6	28.7	30.2	.512	.574
	manual	idle-in-drive	71	10.8	18.3	25.4	.582	.828
		idle-in-neutral		10.7	18.4	25.3	.578	.824

In the case of CO, the manual transmission equipped vehicles had the higher STRR values and exceeded one (1.032) on the Federal Short Cycle.

1.3.9.3 Oxides of Nitrogen Emission

NO_x results are shown in Table 1-66. On the Federal Short Cycle, the STE value of the automatic transmission equipped vehicles (0.610) was 83 percent higher than that of the manual transmission vehicles (0.334).

When tested on the Federal Three-Mode ST, however, the vehicles with manual transmissions recorded higher STE values in both the high and low speed test modes. In the high speed mode, the manual case STE value (0.647) was over twice as large as the automatic case STE value (0.251). In the low speed mode, the higher STE value (0.496) of the manual was 77 percent higher than the automatic transmission STE value (0.281).

On the Federal Short Cycle, the vehicles with manual transmissions had lower STRR values than those equipped with automatic transmissions. On the Federal Three-Mode, this was reversed; the manual transmission case was higher by a factor or two or more and exceeded one (1.538) on the high-speed test mode.

1.3.9.4 Multiple Constituent Tests

The three-constituent test results on a transmission type basis are summarized in Table 1-67. In the Federal Short Cycle, the vehicles with manual transmissions had an STE value (0.870) 7 percent higher than that of the vehicles with automatic transmissions (0.813).

With the idle in neutral and best combination of test modes on the Federal Three-Mode ST, the manual transmission case had higher STE values, as on the Federal Short Cycle. The idle in neutral STE advantage of the manual (0.694) over the automatic (0.575) was 21 percent.

Table 1-66. Comparison of Short Test NO_x Results by Transmission Type; All Three Cities; Predicted Population; Bounded Errors of Commission Method (E_c set at 5 percent)

Short Test	Transmission Type	Test Mode	Number of Vehicles	Parameter, %			STE	STRR
				E_c	E_o	FF		
Federal Short Cycle	all		300	5.0	8.4	12.8	.604	.840
	automatic		229	5.6	9.4	14.7	.610	.842
	manual		71	1.0	6.3	3.2	.334	.442
Federal 3-Mode	all	high	300	5.0	14.6	6.6	.310	.547
		low		5.0	14.8	6.4	.301	.538
	automatic	high	229	3.4	18.0	6.0	.251	.392
		low		4.4	17.3	6.8	.281	.465
	manual	high	71	10.6	4.2	7.7	.647	1.538
		low		6.0	6.0	6.0	.496	1.00

Table 1-67. Comparison of Short Test Multiple Constituent Results by Transmission Type; All Three Cities; Predicted Population; Bounded Errors of Commission Method (E_c set at 5 percent)

Short Test	Transmission Type	Test Mode	Number of Vehicles	Parameter, %			STE	STRR
				E_c	E_o	FF		
Federal Short Cycle	all		300	7.0	11.7	53.7	.821	.928
	automatic		279	7.0	13.1	56.8	.813	.913
	manual		71	7.0	7.0	46.7	.870	1.00
Federal 3-Mode	all	idle-in-drive	300	6.3	19.3	46.0	.704	.801
		idle-in-neutral		4.7	26.3	39.0	.597	.669
		best(a)		4.3	22.0	43.3	.663	.714
	automatic	idle-in-drive	229	5.7	20.5	49.3	.706	.788
		idle-in-neutral		2.6	29.7	40.2	.575	.613
		best(a)		2.2	24.4	45.4	.650	.682
	manual	idle-in-drive	71	8.4	15.5	35.2	.694	.860
		idle-in-neutral		11.3	15.5	35.2	.694	.917
		best(a)		11.3	14.1	36.6	.722	.945

(a) Best individual modes are HC in drive, CO in drive, and NO_x at high speed.

With regard to rejection ratio, the vehicles with manual transmissions had higher STRR values on both STs, and reached 1.0 on the Federal Short Cycle.

1.3.10 Effect of Manufacturer

The variation of short test effectiveness and rejection ratio as a function of vehicle manufacturer is summarized in Tables 1-68 through 1-71 for the Federal Short Cycle and the better individual test modes of the Federal Three-Mode ST.

1.3.10.1 Hydrocarbon Emission

In the case of HC (Table 1-68) on the Federal Short Cycle, the STE values of GM, Ford, and Chrysler were all similar (in 0.638 to 0.676 range). AMC was considerably lower (0.491), and the "others" category (principally small imports) were intermediate in value (0.544).

The above characteristics were not present with the idle in drive test mode of the Federal Three-Mode ST. Here, the GM vehicles were considerably higher (0.511) and Ford considerably lower (0.195) than the fleet average STE value (0.375). Chrysler, AMC, and "others" were very similar (0.318 to 0.364) and near the fleet average. The idle in neutral trends were similar to the idle in drive trends.

With regard to rejection ratio, the manufacturers were all roughly comparable on the Federal Short Cycle except for Ford, with an STRR value of 0.992. On the Federal Short Cycle (idle in drive), Ford had the lowest STRR value (0.286) and AMC had the highest (1.00). AMC had had the lowest STRR value on the Federal Short Cycle (0.509).

1.3.10.2 Carbon Monoxide Emission

The results for CO are given in Table 1-69. On the Federal Short Cycle, GM, Ford, and Chrysler vehicles (as in the case of HC), all had similar STE values (in 0.652 to 0.732 range). AMC vehicles had the lowest STE (0.510) and the "others" category had the highest STE (0.790).

Table 1-68. Comparison of Short Test HC Results by Manufacturer; All Three Cities; Predicted Population; Bounded Errors of Commission Method (E_c set at 5 percent)

Short Test	Manufacturer	Test Mode	Number of Vehicles	Parameter, % E_c	E_o	FF	STE	STRR
Federal Short Cycle	all		300	5.0	13.0	18.7	.589	.748
	GM		99	3.9	10.1	21.0	.676	.801
	Ford		61	8.8	9.0	16.2	.642	.992
	Chrysler		36	3.6	20.7	36.5	.638	.701
	AMC		18	0.4	11.3	10.9	.491	.509
	other		86	5.1	15.0	17.9	.544	.699
Federal 3-Mode	all	idle-in-drive	300	5.0	19.8	11.9	.375	.533
		idle-in-neutral		5.0	21.0	10.7	.338	.495
	GM	idle-in-drive	99	4.5	15.2	15.9	.511	.656
		idle-in-neutral	•	5.2	15.9	15.2	.489	.656
	Ford	idle-in-drive	61	2.3	20.3	4.9	.195	.286
		idle-in-neutral		3.6	19.8	5.5	.217	.360
	Chrysler	idle-in-drive	36	3.7	36.4	20.8	.364	.428
		idle-in-neutral		7.8	29.1	17.6	.377	.448
	AMC	idle-in-drive	18	5.1	14.6	7.5	.340	0.570
		idle-in-neutral		3.9	16.3	5.8	.263	.439
	other	idle-in-drive	86	6.1	22.5	10.5	.318	.503
		idle-in-neutral		4.6	25.8	7.1	.216	.356

Table 1-69. Comparison of Short Test CO Results by Manufacturer; All Three Cities; Predicted Population; Bounded Errors of Commission Method (E_c set at 5 percent)

Short Test	Manufacturer	Test Mode	Number of Vehicles	Parameter, %			STE	STRR
				E_c	E_o	FF		
Federal Short Cycle	all		300	5.0	16.7	37.1	.690	.783
	GM		99	2.4	18.2	35.8	.663	.707
	Ford		61	4.8	14.4	39.4	.732	.822
	Chrysler		36	0.2	28.1	52.5	.652	.654
	AMC		18	1.2	14.7	15.3	.510	.550
	other		86	14.0	8.9	33.3	.790	1.121
Federal 3-Mode	all	idle-in-drive	300	5.0	24.4	31.4	.562	.652
		idle-in-neutral		5.0	26.6	29.3	.524	.614
	GM	idle-in-drive	99	2.0	26.7	31.1	.538	.573
		idle-in-neutral		2.6	28.9	28.9	.500	.545
	Ford	idle-in-drive	61	4.2	28.3	29.3	.509	.582
		idle-in-neutral		3.1	31.7	26.0	.451	.504
	Chrysler	idle-in-drive	36	9.5	8.2	71.8	.898	1.016
		idle-in-neutral		10.1	8.4	71.7	.896	1.021
	AMC	idle-in-drive	18	2.5	14.2	15.7	.525	.609
		idle-in-neutral		1.0	14.3	15.6	.522	.555
	other	idle-in-drive	86	12.7	16.6	25.6	.607	.908
		idle-in-neutral		12.1	20.3	21.9	.519	.806

Using the idle in drive test mode of the Federal Three-Mode ST, all vehicles except Chrysler had STE values (0.509 to 0.607) reasonably close to the fleet average (0.562). The Chrysler vehicles had a much higher STE value (0.898). The idle-in-neutral STE results paralleled the idle-in-drive results.

In the case of CO rejection ratio, on the Federal Short Cycle the major domestic manufacturers were similar in STRR value range; the "others" category (principally small imported cars) exceeded an STRR value of one (1.121). On the Federal Three-Mode, the "others" category had an STRR value of slightly less than one, while Chrysler vehicles exceeded one (1.016 in idle-in-drive test mode).

1.3.10.3 Oxides of Nitrogen Emission

NO_x results are shown in Table 1-70. On the Federal Short Cycle, the AMC (0.957) and Chrysler (0.817) vehicles were considerably above the fleet average (0.604). Ford had the lowest STE value (0.463), followed by "others" (0.492) and GM (0.564).

The NO_x versus manufacturer trends for the high speed mode of the Federal Three-Mode ST are considerably different. AMC, the highest on the Federal Short Cycle, has the lowest STE value (0.087). Only Chrysler (0.349) and "others" (0.467) are above the fleet average (0.310). Ford (0.210) and GM (0.229) are both below the fleet average.

The low speed test mode results are similar only for GM, AMC, and the "others" category. Chrysler had a very high STE value (0.755) in the low speed mode, while Ford had a very low STE value (0.065) in the low speed mode.

In terms of NO_x rejection ratio, on the Federal Short Cycle all manufacturers were similar in STRR value except for AMC which had a value of 2.463. On the Federal Three-Mode, AMC was quite low in STRR (0.322 in low-speed test mode), while Chrysler recorded the highest STRR value (2.129 on the low-speed mode).

Table 1-70. Comparison of Short Test NO_x Results by Manufacturer; All Three Cities; Predicted Population; Bounded Errors of Commission Method (E_c set at 5 percent)

Short Test	Manufacturer	Test Mode	Number of Vehicles	Parameter, %			STE	STRR
				E_c	E_o	FF		
Federal Short Cycle	all		300	5.0	8.4	12.8	.604	.840
	GM		99	1.6	8.8	11.4	.564	.644
	Ford		61	3.5	16.1	13.9	.463	.580
	Chrysler		36	23.6	2.9	13.3	.817	2.278
	AMC		18	14.5	1.4	30.1	.957	1.416
	other		86	2.5	7.9	7.6	.492	.652
Federal 3-Mode	all	high	300	5.0	14.6	6.6	.310	.547
		low		5.0	14.8	6.4	.302	.538
	GM	high	99	4.2	15.5	4.6	.229	.438
		low		2.8	15.3	4.9	.243	.381
	Ford	high	61	1.4	23.7	6.3	.210	.257
		low		0.4	28.1	2.0	.065	.078
	Chrysler	high	36	7.1	10.6	5.7	.349	.790
		low		22.4	4.0	12.3	.755	2.129
	AMC	high	18	0.2	28.7	2.7	.087	.092
		low		4.2	24.0	5.2	.177	.322
	other	high	86	7.5	7.6	6.6	.467	.993
		low		5.4	7.9	7.6	.489	.839

1.3.10.4 Multiple Constituent Tests

The three-constituent test results for both STs on a manufacturer basis are summarized in Table 1-71. In the case of the Federal Short Cycle, AMC (0.916), GM (0.877), and "others" (0.875) were above the fleet average (0.821), whereas Ford (0.700) and Chrysler (0.742) were below the fleet average STE value.

These trends are changed using the idle in drive test mode of the Federal Three-Mode ST (and the best combination of test modes, as well). On this basis, GM (0.800), Chrysler (0.775), and "others" (0.729) have the highest STE values, and Ford (0.500) and AMC (0.583) are the lowest. The idle in neutral trends are similar to the idle in drive trends.

With regard to rejection ratio, AMC (1.165) and the "others" category (1.041) both exceeded STRR values of one on the Federal Short Cycle. All manufacturers had STRR values less than one on the Federal Three-Mode ST, with AMC and Ford having the lower STRR values.

1.3.11 Effect of Manufacturer and Engine Displacement Group

The foregoing analyses indicated that, when the ST cut-points were based on a 5 percent E_c rate for the total 300-vehicle pooled fleet, there were possible inequities in terms of CO and NO_x discrimination for the smaller vehicles with low displacement engines. This was exemplified by the higher E_c and concomitant STRR values for the 150-CID and less displacement group, the 2500-lb and less weight group, the fuel injected vehicles, and the manual transmission-equipped vehicles. The small CID, low vehicle weight, and manual transmission factors are all typical attributes of the small vehicle class. Fuel injection, at its present degree of usage, is also principally restricted to the small vehicle class.

Therefore, in order to gain further insight into this phenomenon, an additional contingency table analysis was made wherein the ST cut-points were determined for each CID class and were based on a 5 percent E_c rate for that CID class alone, not the pooled 300 vehicle fleet as in all

Table 1-71. Comparison of Multiple Constituent Results by Manufacturer; All Three Cities; Predicted Population; Bounded Errors of Commission Method (E_c set at 5 percent)

Short Test	Manufacturer	Test Mode	Number of Vehicles	Parameter, %			STE	STRR
				E_c	E_o	FF		
Federal Short Cycle	all		300	7.0	11.7	53.7	.821	.928
	GM		99	2.0	8.1	57.6	.877	.907
	Ford		61	8.2	19.7	45.9	.700	.825
	Chrysler		36	8.3	22.2	63.9	.742	.839
	AMC		18	16.7	5.6	61.1	.916	1.165
	other		86	9.3	7.0	48.8	.875	1.041
Federal 3-Mode	all	idle-in-drive	300	6.3	19.3	46.0	.704	.801
		idle-in-neutral		4.7	26.3	39.0	.597	.669
		best[(a)]		4.3	22.0	43.3	.663	.714
	GM	idle-in-drive	99	7.1	13.1	52.5	.800	.909
		idle-in-neutral		1.0	20.2	45.5	.693	.708
		best[(a)]		1.0	20.2	45.5	.693	.708
	Ford	idle-in-drive	61	1.6	32.8	32.8	.500	.518
		idle-in-neutral		1.6	37.7	27.9	.425	.450
		best[(a)]		1.6	31.2	34.4	.524	.534
	Chrysler	idle-in-drive	36	5.6	19.4	66.7	.775	.840
		idle-in-neutral		5.6	19.4	66.7	.775	.840
		best[(a)]		5.6	19.4	66.7	.775	.840
	AMC	idle-in-drive	18	5.6	27.8	38.9	.583	.667
		idle-in-neutral		5.6	50.0	16.7	.250	.334
		best[(a)]		0.0	44.4	27.2	.408	.408
	other	idle-in-drive	86	9.3	15.1	40.7	.729	.896
		idle-in-neutral		10.5	23.3	32.6	.583	.771
		best[(a)]		10.5	14.0	41.9	.749	.937

[(a)] Best individual modes are HC in drive, CO in drive, and NO_x at high speed previously discussed results. The results of this investigation are reported below.

1.3.11.1 150 CID and Less Displacement Group

1.3.11.1.1 Hydrocarbon Emission

Table 1-72 presents the HC results for the 95-vehicle 150 CID and less group. On the Federal Short Cycle, all manufacturers except Toyota (0.273) and VW (0.098) had STE values reasonably close to the fleet average value of 0.595. None had STRR values of one or above.

On the Federal Three-Mode ST (idle in drive test mode), the STE values of GM (0.575) and Honda (0.683) were well above the fleet average (0.318). Those of Toyota (0.127) were considerably below the fleet average. All STRR values were below one except Honda, which had a value of 1.037.

1.3.11.1.2 Carbon Monoxide Emission

As shown in Table 1-73, on the Federal Short Cycle all manufacturers had STE values reasonably close to the fleet average of 0.567 except Ford (0.070) and Toyota (0.251); Datsun was intermediate in value (0.374). None had STRR values of one or above.

On the Federal Three-Mode ST (idle in drive test mode), Ford again had a very low STE value (0.002) compared to the fleet average of 0.411. The other manufacturers had STE values near the fleet average except for GM (0.806) and Datsun (0.722), who were well above the average. Again, no manufacturer class had STRR values exceeding one.

1.3.11.1.3 Oxides of Nitrogen Emission

In terms of STE value on the Federal Short Cycle (Table 1-74), both Honda (0) and VW (0.154) registered notable exceptions to the fleet average value of 0.628. With regard to rejection ratio, both Ford (2.039) and VW (1.077) had STRR values in excess of one.

On the Federal Three-Mode ST (high speed mode), the STE values of Ford (0.031), Datsun (0.105), and Toyota (0.104) were all well

Table 1-72. Comparison of HC Results for 150 CID and Less Group; by Manufacturer; All Three Cities; Predicted Population; Bounded Errors of Commission Method (E_c set at 5 percent)

Short Test	Manufacturer	Test Mode	Number of Vehicles	Parameter, %			STE	STRR
				E_c	E_o	FF		
Federal Short Cycle	all		95	5.0	13.0	19.1	.595	.439
	GM		12	2.9	13.4	20.5	.605	.690
	Ford		6	2.1	5.4	13.9	.720	.829
	Chrysler							
	AMC							
	Datsun		8	3.9	6.7	41.7	.862	.942
	Toyota		9	0.3	31.5	11.8	.273	.279
	VW		21	2.7	18.9	17.7	.484	.557
	Honda		6	4.9	7.4	0.8	.098	.695
	others		33	7.2	10.3	19.4	.653	.896
Federal 3-Mode	all	idle-in-drive	95	5.0	21.9	10.2	.318	.474
		idle-in-neutral	95	5.0	23.4	8.7	.271	.427
	GM	idle-in-drive	12	11.3	14.4	19.5	.575	.909
		idle-in-neutral		10.2	13.6	20.3	.599	.900
	Ford	idle-in-drive	6	3.3	13.3	6.0	.311	.482
		idle-in-neutral		5.2	12.5	6.7	.349	.620
	Datsun	idle-in-drive	8	5.4	30.3	18.1	.374	.486
		idle-in-neutral		.9	44.9	3.6	.074	.092
	Toyota	idle-in-drive	9	2.8	37.8	5.5	.127	.192
		idle-in-neutral		1.5	40.2	3.1	.072	.106

Table 1-72. Comparison of HC Results for 150 CID and Less Group; by Manufacturer; All Three Cities; Predicted Population; Bounded Errors of Commission Method (E_c set at 5 percent) (Continued)

Short Test	Manufacturer	Test Mode	Number of Vehicles	Parameter, %			STE	STRR
				E_c	E_o	FF		
Federal 3-Mode (continued)	VW[a]	idle-in-drive	21	4.2	23.4	13.1	.359	.474
		idle-in-neutral		4.6	22.3	14.2	.389	.515
	Honda	idle-in-drive	6	2.9	2.6	5.6	.683	1.037
		idle-in-neutral		5.6	1.5	6.6	.815	1.488
	others	idle-in-drive	33	4.2	21.9	7.8	.263	.404
		idle-in-neutral		3.7	25.1	4.7	.158	.282

[a] VW category includes VW, Audi, and Porsche

Table 1-73. Comparison of CO Results for 150 CID and Less Group; by Manufacturer; All Three Cities; Predicted Population; Bounded Errors of Commission Method (E_c set at 5 percent)

Short Test	Manufacturer	Test Mode	Number of Vehicles	Parameter, %			STE	STRR
				E_c	E_o	FF		
Federal Short Cycle	all		95	5.0	19.4	25.4	.567	.679
	GM		12	0.1	36.9	40.5	.523	.525
	Ford		6	0.0	23.8	1.8	.070	.070
	Chrysler							
	AMC							
	Datsun		8	0.4	33.1	19.8	.374	.382
	Toyota		9	3.7	25.6	8.6	.251	.360
	VW		21	4.9	24.5	23.4	.489	.591
	Honda		6	0	0	0	0	0
	others		33	6.8	10.7	30.8	.742	.906
Federal 3-Mode	all	idle-in-drive	95	5.0	26.4	18.4	.411	.522
		idle-in-neutral		5.0	28.8	16.0	.357	.469
	GM	idle-in-drive	12	6.7	15.4	64.1	.806	.903
		idle-in-neutral		6.6	15.7	63.8	.803	.886
	Ford	idle-in-drive	6	.1	25.6	0.05	.002	.006
		idle-in-neutral		.06	25.6	0.03	.001	.004
	Datsun	idle-in-drive	8	10.9	14.7	38.2	.722	.928
		idle-in-neutral		4.0	39.5	13.3	.252	.328
	Toyota	idle-in-drive	9	4.7	21.6	12.6	.368	.506
		idle-in-neutral		3.9	29.0	5.2	.152	.266

Table 1-73. Comparison of CO Results for 150 CID and Less Group; by Manufacturer; All Three Cities; Predicted Population; Bounded Errors of Commission Method (E_c set at 5 percent) (Continued)

Short Test	Manufacturer	Test Mode	Number of Vehicles	Parameter, %			STE	STRR
				E_c	E_o	FF		
Federal 3-Mode (continued)	VW	idle-in-drive	21	8.4	30.0	18.3	.379	.552
		idle-in-neutral		8.9	31.6	16.7	.346	.530
	Honda	idle-in-drive	6	0.0	0.0	0.0	0	0
		idle-in-neutral		0.0	0.0	0.0	0	0
	others	idle-in-drive	33	2.8	26.5	15.0	.361	.429
		idle-in-neutral		2.9	30.0	11.5	.277	.347

Table 1-74. Comparison of NO_x Results for 150 CID and Less Group; by Manufacturer; All Three Cities; Predicted Population; Bounded Errors of Commission Method (E_c set at 5 percent)

Short Test	Manufacturer	Test Mode	Number of Vehicles	Parameter, %			STE	STRR
				E_c	E_o	FF		
Federal Short Cycle	all		95	5.0	5.8	9.8	.628	.949
	GM		12	3.9	2.2	8.8	.800	1.155
	Ford		6	19.2	5.8	7.1	.550	2.039
	Chrysler							
	AMC							
	Datsun		8	2.9	10.8	14.7	.577	.690
	Toyota		9	0.7	35.9	28.6	.443	.454
	VW		21	1.2	1.1	0.2	.154	1.077
	Honda		6	0	0.1	0	0	0
	others		33	1.7	3.8	8.8	.698	.833
Federal 3-Mode	all	high	95	5.0	9.0	6.5	.419	.742
		low		5.0	9.0	5.2	.366	.789
	GM	high	12	9.9	2.7	8.3	.755	1.655
		low		11.0	5.9	5.2	.468	1.459
	Ford	high	6	.8	12.5	.4	.031	.093
		low		.01	12.9	.04	.003	.004
	Datsun	high	8	27.2	23.8	2.8	.105	1.128
		low		.9	21.0	4.4	.173	.209
	Toyota	high	9	.34	57.0	6.6	.104	.109
		low		3.8	21.7	37.7	.635	.698

Table 1-74. Comparison of NO_x Results for 150 CID and Less Group; by Manufacturer; All Three Cities; Predicted Population; Bounded Errors of Commission Method (E_c set at 5 percent) (Continued)

Short Test	Manufacturer	Test Mode	Number of Vehicles	Parameter, %			STE	STRR
				E_c	E_o	FF		
Federal 3-Mode (continued)	VW	high	21	.6	.9	.4	.308	.769
		low		10.3	.3	.9	.750	9.333
	Honda	high	6	.7	.1	.03	.231	5.615
		low		.8	.01	0.0	0	8.00
	others	high	33	2.4	9.8	2.8	.222	.413
		low		2.4	8.6	4.0	.318	.508

below the fleet average of 0.419, whereas the GM value (0.755) was quite high. In terms of ST rejection ratio, GM (1.655), Datsun (1.128), and Honda (5.615) all exceeded an STRR value of one.

1.3.11.1.4 Multiple Constituent Tests

As shown in Table 1-75, on the Federal Short Cycle, all manufacturers were reasonably close to the fleet average STE value of 0.763 except Honda, which registered a value of zero. In terms of STRR value, all were below one except for Datsun (1.200).

On the Federal Three-Mode ST (idle in drive test mode), Ford (0.250) and Toyota (0.285) had the lowest STE values. GM (1.00), Honda (1.00), and VW (0.700) had the highest values. With regard to rejection ratio, GM (1.111) exceeded an STRR value of 1.00.

1.3.11.2 151 to 259 CID Group

1.3.11.2.1 Hydrocarbon Emission

Table 1-76 presents the HC results for the 54-vehicle 151 to 259 CID group. On the Federal Short Cycle, Chrysler (0.241) was well below the fleet average STE value of 0.487, and Ford (0.671) was well above the average. Ford (1.043) also exceeded the STRR value of one.

On the Federal Three-Mode ST (idle in drive test mode), the STE values of GM (0.703) and Chrysler (0.707) were quite high. Ford (0.062), AMC (0.170), and the others were all very low. Only Chrysler (1.063) exceeded an STRR value of one.

1.3.11.2.2 Carbon Monoxide Emission

As shown in Table 1-77, on the Federal Short Cycle all manufacturers had STE values reasonably close to the fleet average of 0.737. Only Ford (1.051) slightly exceeded an STRR value of one.

On the Federal Three-Mode ST (idle in drive test mode), General Motors (0.781) and Chrysler (0.803) had the highest STE values; the rest fell in the 0.360 to 0.551 range. Only Chrysler (1.025) exceeded an STRR value of one.

Table 1-75. Comparison of Multiple Constituent Results for 150 CID and Less Group; by Manufacturer; All Three Cities; Predicted Population; Bounded Errors of Commission Method (E_c set at 5 percent)

Short Test	Manufacturer	Test Mode	Number of Vehicles	Parameter, % E_c	Parameter, % E_o	Parameter, % FF	STE	STRR
Federal Short Cycle	all		95	1.1	13.7	44.2	.763	.955
	GM		12	0.0	25.0	50.0	.667	.667
	Ford		6	0.0	33.3	33.3	.500	.500
	Chrysler							
	AMC							
	Datsun		8	12.5	0.0	62.50	1.00	1.200
	Toyota		9	0.0	22.2	55.6	.715	.715
	VW		21	0.0	9.5	38.1	.800	.800
	Honda		6	0.0	16.7	0.0	0	0
	others		33	0.0	9.1	48.5	.842	.842
Federal 3-Mode	all	idle-in-drive	95	6.3	27.4	30.5	.527	.636
		idle-in-neutral		5.3	35.8	22.1	.382	.466
		best[(a)]		5.3	28.4	29.5	.509	.601
	GM	idle-in-drive	12	8.3	0.0	75.0	1.00	1.111
		idle-in-neutral		0.0	16.7	58.3	.777	.777
		best[(a)]		8.3	16.7	58.3	.777	.888
	Ford	idle-in-drive	6	0.0	50.0	16.7	.250	.250
		idle-in-neutral		0.0	50.0	16.7	.250	.250
		best[(a)]		0.0	50.0	16.7	.250	.250
	Datsun	idle-in-drive	8	12.5	37.5	25.0	.400	.600
		idle-in-neutral		12.5	50.0	12.5	.200	.400
		best[(a)]		12.5	25.0	37.5	.600	.800

[(a)] This category includes 1 Datsun and 1 VW

Table 1-75. Comparison of Multiple Constituent Results for 150 CID and Less Group; by Manufacturer; All Three Cities; Predicted Population; Bounded Errors of Commission Method (E_c set at 5 percent) (Continued)

Short Test	Manufacturer	Test Mode	Number of Vehicles	Parameter, %			STE	STRR
				E_c	E_o	FF		
Federal 3-Mode (continued)	Toyota	idle-in-drive	9	0.0	55.6	22.2	.285	.285
		idle-in-neutral		0.0	55.6	22.2	.285	.285
		best[a]		0.0	55.6	22.2	.285	.285
	VW	idle-in-drive	21	14.3	14.3	33.3	.700	1.000
		idle-in-neutral		14.3	14.3	33.3	.700	1.000
		best[a]		9.5	14.3	33.3	.700	.899
	Honda	idle-in-drive	6	0.0	0.0	16.7	1.00	1.00
		idle-in-neutral		0.0	0.0	16.7	1.00	1.00
		best[a]		0.0	0.0	16.7	1.00	1.00
	others	idle-in-drive	33	3.0	36.4	21.2	.368	.420
		idle-in-neutral		3.0	51.5	6.1	.106	.158
		best[a]		3.0	36.4	21.2	.368	.420

(a) Best individual modes are HC and CO in drive, and NO_x at high speed.

Table 1-76. Comparison of HC Results for 151 to 259 CID Group; by Manufacturer; All Three Cities; Predicted Population; Bounded Errors of Commission Method (E_c set at 5 percent)

Short Test	Manufacturer	Test Mode	Number of Vehicles	Parameter, %			STE	STRR
				E_c	E_o	FF		
Federal Short Cycle	all		54	5.0	14.0	13.3	.487	.670
	GM		13	1.8	13.1	18.6	.587	. 44
	Ford		13	6.0	5.3	10.8	.671	1.043
	Chrysler		7	1.5	14.5	4.6	.241	.319
	AMC		12	1.9	16.9	21.0	.554	.604
	Datsun							
	Toyota							
	VW							
	Honda							
	others		7	4.9	0.7	9.1	.929	1.556
	others[a]		9	3.6	21.1	12.0	.363	.471
Federal 3-Mode	all	idle-in-drive	54	5.0	18.8	8.4	.309	.493
		idle-in-neutral		5.0	20.0	7.2	.265	.449
	GM	idle-in-drive	13	6.5	9.4	22.3	.703	.909
		idle-in-neutral		8.4	14.4	17.3	.546	.811
	Ford	idle-in-drive	13	1.0	15.1	1.0	.062	.124
		idle-in-neutral		.44	15.5	1.0	.061	.087
	Chrysler	idle-in-drive	7	6.8	5.6	13.5	.707	1.063
		idle-in-neutral		3.2	7.7	11.6	.601	.767

[a] This category includes 1 Datsun and 1 VW

Table 1-76. Comparison of HC Results for 151 to 259 CID Group; by Manufacturer; All Three Cities; Predicted Population; Bounded Errors of Commission Method (E_c set at 5 percent) (Continued)

Short Test	Manufacturer	Test Mode	Number of Vehicles	Parameter, %			STE	STRR
				E_c	E_o	FF		
Federal 3-Mode (continued)	AMC	idle-in-drive	12	5.3	27.3	5.6	.170	.331
		idle-in-neutral		4.1	28.2	4.7	.143	.267
	others[(a)]	idle-in-drive	9	1.7	31.1	2.0	.060	.111
		idle-in-neutral		1.7	31.5	1.6	.048	.100
	others	idle-in-drive	7	3.1	8.3	1.5	.153	.469
		idle-in-neutral		3.1	9.2	.7	.071	.384

(a) This category includes 1 Datsun and 1 VW

Table 1-77. Comparison of CO Results for 151 to 259 CID Group; by Manufacturer; All Three Cities; Predicted Population; Bounded Errors of Commission Method (E_c set at 5 percent)

Short Test	Manufacturer	Test Mode	Number of Vehicles	Parameter, %			STE	STRR
				E_c	E_o	FF		
Federal Short Cycle	all		54	5.0	14.6	41.0	.737	.827
	GM		13	0.5	20.4	44.1	.684	.691
	Ford		13	8.7	6.4	38.6	.858	1.051
	Chrysler		7	2.6	30.8	38.3	.554	.592
	AMC		12	4.1	16.4	34.5	.678	.758
	Datsun							
	Toyota							
	VW							
	Honda							
	others		7	4.6	5.6	48.4	.896	.981
	others[(a)]		9	5.5	7.8	47.9	.860	.959
Federal 3-Mode	all	idle-in-drive	54	5.0	24.6	34.8	.586	.670
		idle-in-neutral		5.0	32.3	27.1	.456	.540
	GM	idle-in-drive	13	7.4	14.1	50.4	.781	.896
		idle-in-neutral		9.0	30.8	33.6	.522	.661
	Ford	idle-in-drive	13	1.5	36.2	20.4	.360	.387
		idle-in-neutral		1.7	41.1	15.5	.274	.304
	Chrysler	idle-in-drive	7	15.3	13.6	55.5	.803	1.025
		idle-in-neutral		12.3	3.1	68.5	.957	1.128

(a) This category includes 1 Datsun and 1 VW

Table 1-77. Comparison of CO Results for 151 to 259 CID Group; by Manufacturer; All Three Cities; Predicted Population; Bounded Errors of Commission Method (E_c set at 5 percent) (Continued)

Short Test	Manufacturer	Test Mode	Number of Vehicles	Parameter, %			STE	STRR
				E_c	E_o	FF		
Federal 3-Mode (continued)	AMC	idle-in-drive	12	5.3	26.1	24.8	.487	.591
		idle-in-neutral		1.1	30.3	20.6	.405	.426
	others[a]	idle-in-drive	9	1.0	25.0	30.7	.551	.569
		idle-in-neutral		.1	35.0	20.7	.372	.373
	others	idle-in-drive	7	.8	24.5	29.5	.546	.561
		idle-in-neutral		.03	35.5	18.4	.341	.342

[a] This category includes 1 Datsun and 1 VW.

1.3.11.2.3 Oxides of Nitrogen Emission

In terms of STE value on the Federal Short Cycle (Table 1-78), Ford (0.359) had the lowest value and AMC (0.939) had the highest. AMC (1.429) also exceeded an STRR value of one.

On the Federal Three-Mode ST, the low speed test mode was superior for the fleet averaged 151 to 259 CID vehicle group (STE = 0.445 versus 0.230 for the high speed test mode). In this test mode, GM (0.648) and Chrysler (0.819) had the highest STE values, whereas Ford (0.244) and the "others" category (0.038 to 0.122) were quite low in STE value. Both GM (1.032) and Chrysler (1.023) slightly exceeded an STRR value of one.

1.3.11.2.4 Multiple Constituent Tests

As shown in Table 1-79, on the Federal Short Cycle, all manufacturers were reasonably close to the fleet average STE value of 0.812 except Chrysler, which registered a value of 0.334. In terms of STRR value, both Ford and AMC had values of 1.0.

On the Federal Three-Mode ST (idle in drive test mode), GM (1.0) and Chrysler (0.833) had the highest STE values. Ford (0.333), AMC (0.500), and the "others" category (0.400 to 0.500) were below the fleet average value of 0.648. Chrysler had an STRR value of 1.0 and GM recorded a value of 1.223.

1.3.11.3 260 CID and Greater Group

1.3.11.3.1 Hydrocarbon Emission

Table 1-80 presents the HC results for the 151-vehicle 260 CID and greater group. On the Federal Short Cycle, all manufacturers (domestic only) were fairly close together in terms of STE value. None exceeded an STRR value of one.

On the Federal Three-Mode (idle in drive test mode), the STE value of Ford (0.299) was well below that of GM (0.531) and Chrysler (0.520). No manufacturer exceeded an STRR value of one.

Table 1-78. Comparison of NO_x Results for 151 to 259 CID Group; by Manufacturer; All Three Cities; Predicted Population; Bounded Errors of Commission Method (E_c set at 5 percent)

Short Test	Manufacturer	Test Mode	Number of Vehicles	Parameter, %			STE	STRR
				E_c	E_o	FF		
Federal Short Cycle	all		54	5.0	7.5	12.5	.625	.875
	GM		13	0.5	10.8	11.0	.505	.528
	Ford		13	6.2	8.4	4.7	.359	.832
	Chrysler		7	5.0	6.9	27.4	.799	.945
	AMC		12	13.6	1.7	26.0	.939	1.429
	Datsun							
	Toyota							
	VW							
	Honda							
	others		7	0.6	7.5	3.0	.286	.343
	others[a]		9	0.6	7.6	3.9	.339	.391
Federal 3-Mode	all	high	54	5.0	15.4	4.6	.230	.480
		low		5.0	11.1	8.9	.445	.695
	GM	high	13	5.8	20.1	1.8	.082	.347
		low		8.4	7.7	14.2	.648	1.032
	Ford	high	13	2.9	9.0	4.1	.313	.534
		low		1.5	9.9	3.2	.244	.359
	Chrysler	high	7	7.4	20.7	13.5	.395	.611
		low		7.0	6.2	28.0	.819	1.023

[a] This category includes 1 Datsun and 1 VW

Table 1-78. Comparison of NO_x Results for 151 to 259 CID Group; by Manufacturer; All Three Cities; Predicted Population; Bounded Errors of Commission Method (E_c set at 5 percent) (Continued)

Short Test	Manufacturer	Test Mode	Number of Vehicles	Parameter, %			STE	STRR
				E_c	E_o	FF		
Federal 3-Mode (continued)	AMC	high	12	2.0	20.0	7.7	.278	.350
		low		5.2	17.6	8.2	.318	.536
	others[a]	high	9	4.8	7.8	3.7	.322	.739
		low		1.3	10.1	1.4	.122	.234
	others	high	7	2.0	9.0	1.5	.143	.333
		low		.4	10.1	.4	.038	.076

[a] This category includes 1 Datsun and 1 VW.

Table 1-79. Comparison of Multiple Constituent Results for 151 to 259 CID Group; by Manufacturer; All Three Cities; Predicted Population; Bounded Errors of Commission Method (E_c set at 5 percent)

Short Test	Manufacturer	Test Mode	Number of Vehicles	Parameter, % E_c	Parameter, % E_o	Parameter, % FF	STE	STRR
Federal Short Cycle	all		54	5.6	13.0	55.6	.812	.892
	GM		13	0.0	15.4	53.9	.779	.778
	Ford		13	0.0	0.0	46.2	1.00	1.00
	Chrysler		7	0.0	57.1	28.6	.334	.334
	AMC		12	8.3	8.3	75.0	.900	1.00
	Datsun							
	Toyota							
	VW							
	Honda							
	others		7	28.6	0.0	71.43	1.0	1.40
	others[(a)]		9	22.2	0.0	66.7	1.0	1.333
Federal 3-Mode	all	idle-in-drive	54	5.6	24.1	44.4	.648	.735
		idle-in-neutral		3.7	35.2	33.3	.486	.540
		best[(b)]		1.8	22.2	46.3	.676	.702
	GM	idle-in-drive	13	15.4	0.0	69.2	1.0	1.223
		idle-in-neutral		13.1	15.7	6.2	.283	.919
		best[(b)]		7.7	15.4	53.8	.777	.888
	Ford	idle-in-drive	13	0.0	30.8	15.4	.333	.333
		idle-in-neutral		0.0	30.8	15.4	.333	.333
		best[(b)]		0.0	23.1	23.1	.500	.500

(a) This category includes 1 Datsun and 1 VW

Table 1-79. Comparison of Multiple Constituent Results for 151 to 259 CID Group; by Manufacturer; All Three Cities; Predicted Population; Bounded Errors of Commission Method (E_c set at 5 percent) (Continued)

Short Test	Manufacturer	Test Mode	Number of Vehicles	Parameter, %			STE	STRR
				E_c	E_o	FF		
Federal 3-Mode (continued)	Chrysler	idle-in-drive	7	14.3	14.3	71.4	.833	1.000
		idle-in-neutral		14.3	14.3	71.4	.833	1.000
		best[(b)]		14.3	14.3	71.4	.833	1.000
	AMC	idle-in-drive	12	0.0	41.7	41.7	.500	.500
		idle-in-neutral		0.0	66.7	16.7	.200	.200
		best[(b)]		0.0	41.7	41.7	.500	.500
	others[(a)]	idle-in-drive	9	0.0	33.3	33.3	.500	.500
		idle-in-neutral		0.0	44.4	22.2	.333	.333
		best[(b)]		0.0	33.3	33.3	.500	.500
	others	idle-in-drive	7	0.0	42.9	28.6	.400	.400
		idle-in-neutral		0.0	57.1	14.3	.200	.200
		best[(b)]		0.0	42.9	28.6	.400	.400

[(a)] This category includes 1 Datsun and 1 VW

[(b)] Best individual modes are HC and CO in drive and NO_x at high speed.

Table 1-80. Comparison of HC Results for 260 CID and Greater Group; by Manufacturer; All Three Cities; Predicted Population; Bounded Errors of Commission Method (E_c set at 5 percent)

Short Test	Manufacturer	Test Mode	Number of Vehicles	Parameter, %			STE	STRR
				E_c	E_o	FF		
Federal Short Cycle	all		151	5.0	12.5	20.4	.620	.772
	GM		74	4.0	8.9	21.8	.710	.840
	Ford		42	2.8	11.4	18.0	.612	.707
	Chrysler		29	4.0	20.3	40.5	.666	.731
	AMC		6	0	0	0	0	0
	Datsun							
	Toyota							
	VW							
	Honda							
	others							
Federal 3-Mode	all	idle-in-drive	151	5.0	18.3	14.6	.444	.596
		idle-in-neutral		5.0	19.6	13.3	.404	.556
	GM	idle-in-drive	74	4.0	14.4	16.3	.531	.661
		idle-in-neutral		4.2	15.9	14.8	.482	.619
	Ford	idle-in-drive	42	3.9	20.6	8.8	.299	.432
		idle-in-neutral		5.1	21.2	8.3	.281	.454
	Chrysler	idle-in-drive	29	5.9	29.2	31.6	.520	.617
		idle-in-neutral		6.2	31.1	29.7	.488	.590
	AMC	idle-in-drive	6	0.0	0.0	0.0	0	0
		idle-in-neutral		0.0	0.0	0.0	0	0

1.3.11.3.2 Carbon Monoxide Emission

As shown in Table 1-81, on the Federal Short Cycle, the STE values of all manufacturers were reasonably well grouped, with Chrysler the highest at STE = 0.920. Ford (1.028) slightly exceeded an STRR value of one.

On the Federal Three-Mode (idle in drive test mode), Chrysler again had the highest STE value (0.937) and GM had the lowest (0.631). Both Ford (1.058) and Chrysler (1.041) slightly exceeded an STRR value of one.

1.3.11.3.3 Oxides of Nitrogen Emission

In terms of STE value on the Federal Short Cycle (Table 1-82), AMC had the highest value (0.942) and Ford the lowest (0.385). Both AMC (1.159) and Chrysler (2.554) exceed an STRR value of one.

On the Federal Three-Mode ST, the high speed test mode was superior for the fleet average. In this test mode, Chrysler had the highest STE value (0.479), AMC the lowest (0.86); GM (0.288) and Ford (0.335) were near the fleet average value of 0.343. Only Chrysler (1.488) had an STRR value in excess of one.

1.3.11.3.4 Multiple Constituent Tests

As shown in Table 1-83, on the Federal Short Cycle all manufacturers were reasonably close to the fleet average STE value of 0.904. All manufacturers except Chrysler exceeded an STRR value of one and AMC had an STRR value of 2.0.

On the Federal Three-Mode ST (idle in drive test mode), all manufacturers except AMC were closely grouped in STE value near the fleet average (0.721); AMC recorded an STE value of one. No manufacturer exceeded an STRR value of one.

Table 1-81. Comparison of CO Results for 260 CID and Greater Group; by Manufacturer; All Three Cities; Predicted Population; Bounded Errors of Commission Method (E_c set at 5 percent)

Short Test	Manufacturer	Test Mode	Number of Vehicles	Parameter, % E_c	Parameter, % E_o	Parameter, % FF	STE	STRR
Federal Short Cycle	all		151	5.0	13.0	44.2	.773	.860
	GM		74	5.2	12.2	38.1	.758	.861
	Ford		42	10.1	8.4	52.0	.861	1.028
	Chrysler		29	2.0	6.6	76.4	.920	.945
	AMC		6	0.4	0	0	0	0
	Datsun							
	Toyota							
	VW							
	Honda							
	others							
Federal 3-Mode	all	idle-in-drive	151	5.0	17.8	42.1	.703	.790
		idle-in-neutral		5.0	18.8	41.3	.687	.770
	GM	idle-in-drive	74	3.0	20.1	34.4	.631	.686
		idle-in-neutral		3.5	21.2	33.3	.611	.675
	Ford	idle-in-drive	42	13.0	9.4	52.1	.847	1.058
		idle-in-neutral		10.2	11.6	49.8	.811	.977
	Chrysler	idle-in-drive	29	8.6	5.2	77.8	.937	1.041
		idle-in-neutral		8.9	5.5	77.4	.934	1.041
	AMC	idle-in-drive	6	.2	0.0	0.0	0	0
		idle-in-neutral		.4	0.0	0.0	0	0

Table 1-82. Comparison of NO_x Results for 260 CID and Greater Group; by Manufacturer; All Three Cities; Predicted Population; Bounded Errors of Commission Method (E_c set at 5 percent)

Short Test	Manufacturer	Test Mode	Number of Vehicles	Parameter, %			STE	STRR
				E_c	E_o	FF		
Federal Short Cycle	all		151	5.0	11.5	13.3	.536	.738
	GM		74	1.1	10.9	10.7	.495	.546
	Ford		42	0.6	23.5	14.7	.385	.401
	Chrysler		29	20.9	2.1	10.0	.827	2.554
	AMC		6	9.0	2.4	38.9	.942	1.159
	Datsun							
	Toyota							
	VW							
	Honda							
	others							
Federal 3-Mode	all	high	151	5.0	16.3	8.5	.343	.544
		low		5.0	19.4	5.4	.218	.419
	GM	high	74	4.0	15.3	6.2	.288	.474
		low		1.0	17.6	3.9	.181	.228
	Ford	high	42	3.0	25.4	12.8	.335	.414
		low		.2	35.4	2.8	.073	.078
	Chrysler	high	29	12.2	6.3	5.8	.479	1.488
		low		28.2	2.1	10.0	.826	3.157
	AMC	high	6	0.0	34.9	3.3	.086	.086
		low		2.8	33.4	4.8	.126	.199

Table 1-83. Comparison of Multiple Constituent Results for 260 CID and Greater Group; by Manufacturer; All Three Cities; Predicted Population; Bonded Errors of Commission Method (E_c set at 5 percent)

Short Test	Manufacturer	Test Mode	Number of Vehicles	Parameter, %			STE	STRR
				E_c	E_o	FF		
Federal Short Cycle	all		151	8.0	6.6	62.3	.904	1.020
	GM		74	4.1	4.1	59.5	.937	1.000
	Ford		42	14.3	7.1	64.3	.901	1.101
	Chrysler		29	3.5	13.8	72.4	.840	.881
	AMC		6	33.3	0.0	33.3	1.00	2.000
	Datsun							
	Toyota							
	VW							
	Honda							
	others							
Federal 3-Mode	all	idle-in-drive	151	6.0	19.2	49.7	.721	.808
		idle-in-neutral		5.3	17.9	51.0	.740	.817
		best[(a)]		4.0	19.9	49.0	.711	.769
	GM	idle-in-drive	74	4.0	17.6	46.0	.723	.786
		idle-in-neutral		1.3	17.6	46.0	.723	.744
		best[(a)]		0.0	23.0	40.5	.638	.638
	Ford	idle-in-drive	42	11.9	19.0	52.4	.734	.900
		idle-in-neutral		14.3	16.7	54.8	.766	.966
		best[(a)]		11.9	16.7	54.8	.766	.933

(a) Best individual modes are HC in drive, CO in drive, and NO_x at high speed

Table 1-83. Comparison of Multiple Constituent Results for 260 CID and Greater Group; by Manufacturer; All Three Cities; Predicted Population; Bonded Errors of Commission Method (E_c set at 5 percent) (Continued)

Short Test	Manufacturer	Test Mode	Number of Vehicles	Parameter, %			STE	STRR
				E_c	E_o	FF		
Federal 3-Mode (continued)	Chrysler	idle-in-drive	29	3.4	20.7	65.5	.760	.799
		idle-in-neutral		3.4	17.2	69.0	.800	.840
		best[a]		3.4	13.8	72.4	.840	.879
	AMC	idle-in-drive	6	0.0	33.3	0.0	0	0
		idle-in-neutral		0.0	33.3	0.0	0	0
		best[a]		0.0	33.3	0.0	0	0

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[a] Best individual modes are HC and CO in drive, and NO_x at high speed.

1.3.12 Comparison of Short Test Cut-Points

1.3.12.1 By City

Table 1-84 summarizes the variation of FSC cut-point value for each emission constituent required to result in a 5 percent E_c rate in each individual city and for the pooled 300-vehicle fleet. The pooled fleet values were those used in the contingency table analyses of Sections 1.2.1 through 1.2.10. The cut-point values for all three pollutants are very similar for Chicago and Houston; Phoenix cut-points are higher in each case, with a corresponding impact on the pooled fleet average.

Table 1-85 summarizes similar cut-point values for the Federal Three-Mode ST (idle in drive for HC and CO, and high speed mode for NO_x). In contrast to the Federal Short Cycle, here the HC and CO cut-points for Phoenix are lower than the pooled fleet average and the Chicago cut-points are much higher.

1.3.12.2 By Engine Displacement Group

Table 1-86 summarizes the variation of FSC cut-point value for each emission constituent required to result in a 5 percent E_c rate for each individual CID group and for the pooled 300-vehicle fleet. The CID group values shown were those used in the contingency table analyses of Section 1.2.11. As can be noted, the CO cut-point for the 150 CID and less group is considerably higher than the pooled fleet average. Thus, in the analyses made using pooled fleet cut-points (Sections 1.2.1 through 1.2.10), the small vehicle class should have been and was consistently identified as having a high E_c value and correspondingly high STRR values.

Table 1-87 summarizes similar cut-point values for the Federal Three-Mode ST (idle in drive for HC and CO, and high speed mode for NO_x). Here both CO and NO_x cut-points for the 150 CID and less group are higher than fleet average values. Again, in the analyses of Sections 1.2.1 through 1.2.10, this CID group was consistently identified with high E_c and STRR values because of these cut-point distribution characteristics.

Table 1-84. Comparison of Federal Short Cycle Cut-Points by City (E_c set at 5 percent)

City	No. of Vehicles	ST Cut Points and Standard Errors (gm/mi)					
		HC		CO		NO_x	
		CP(a)	SE(b)	CP	SE	CP	SE
All	300	1.32	0.145	8.40	0.866	2.62	0.219
Chicago	100	1.24	0.283	7.99	1.240	2.54	0.355
Houston	100	1.24	0.181	7.49	1.327	2.56	0.360
Phoenix	100	1.44	0.267	9.48	1.916	2.77	0.412

(a) CP = cut point.

(b) SE = standard error.

Table 1-85. Comparison of Federal Three-Mode Cut-Points by City (E_c set at 5 percent)

City	No. of Vehicles	ST Cut-Points and Standard Errors (ppm)(a)					
		HC		CO		NO_x	
		CP(c)	SE(d)	CP	SE	CP	SE
All	300	184	26	7,081	1,251	2,265	243
Chicago	100	241	78	10,145	2,627	2,026	410
Houston	100	132	27	6,175	2,432	2,172(e)	393(e)
Phoenix	100	174	31	5,494	1,510	2,439	379

(a) Idle in drive test mode

(b) High speed test mode

(c) Cut-point

(d) Standard error

(e) The best mode for NO_x for Houston was found to be the low speed mode. The cut-point and standard error for NO_x low speed are 1500 ppm and 372 ppm, respectively.

Table 1-86. Comparison of Federal Short Cycle Cut-Points by Engine Displacement (E_c set at 5 percent)

Engine Displacement Group	No. of Vehicles	ST Cut-Points and Standard Errors (gm/mi)					
		HC		CO		NO_x	
		CP[a]	SE[b]	CP	SE	CP	SE
All	300	1.32	0.145	8.40	0.866	2.62	0.219
150 CID and Less	95	1.28	0.234	13.10	1.920	2.37	0.439
151 to 259 CID	54	1.27	0.464	6.24	1.124	2.62	0.440
260 CID and Greater	151	1.35	0.192	5.61	0.821	2.78	0.285

(a)CP = cut point.

(b)SE = standard error.

Table 1-87. Comparison of Federal Three-Mode Cut-Points by Engine Displacement (E_c set at 5 percent)

Engine Displacement Group	No. of Vehicles	ST Cut-Points and Standard Errors (ppm)					
		HC(a)		CO(a)		NO_x(b)	
		CP(c)	SE(d)	CP	SE	CP	SE
All Three Cities	300	184	26	7,081	1,251	2,265	243
150 CID and Less	95	219	57	18,382	5,863	2,805	665
151 to 259 CID	54	213	79	7,063	2,488	1,985(e)	446(e)
260 CID and Greater	151	151	26	2,655	607	1,986	252

(a)Idle in drive test mode

(b)High speed test mode

(c)Cut-point

(d)Standard error

(e)The best mode for NO_x on this engine displacement was found to be the low speed mode. The cut-point and standard error for the low speed NO_x are 1396 ppm and 423 ppm, respectively.

1.3.13 Effect of Cut-Point Selection Method on STE Values

As discussed in Sections 1.3.1 through 1.3.11 and elsewhere, the use of cut-points based on pooled fleet characteristics can result in higher than average rejection ratios (STRRs) for the smaller cars with small engines, particularly for CO and NO_x pollutants. Since it might prove beneficial, for instance, to select cut-points as a function of engine size (i.e., CID group) to minimize such potential inequities, an analysis was made whereby each of the three CID-groups was tested with cut-points selected to result in a 5 percent E_c rate for each CID-group, rather than 5 percent for the pooled fleet irrespective of CID group. These results are compared with the results of Sections 1.3.1 through 1.3.4 in Table 1-88 for the Federal Short Cycle and in Table 1-89 for the Federal Three-Mode.

In the case of the Federal Short Cycle, use of the CID-grouping for cut-point selection resulted in very minor improvements in the STE value for HC, CO, and multiple constituents and a very slight decrease in NO_x STE value. In the case of the Federal Three-Mode, HC, CO, and NO_x (high speed only) STE values were slightly improved and the multiple constituents and NO_x (low speed only) STE values were slightly decreased. The use of CID-grouped cut-points would have the advantage of avoiding possible inequities associated with excessive ST failures of small vehicles.

Table 1-88. Federal Short Cycle STE Comparison; 5 Percent E_c Fleet Average vs 5 Percent E_c for Each of Three CID Groups

Pollutant	Short Test Effectiveness (STE)[a]	
	5% E_c Fleet Average	5% for Each of Three CID Groups[b]
HC	0.589	0.592
CO	0.690	0.711
NO_x	0.604	0.573
Multiple Constituents[c]	0.821	0.847

[a] $STE = \frac{\%FF}{\%Eo + \%FF}$

[b] 150 CID and less
151 to 259 CID
260 and greater CID

[c] Car fails if any of the HC, CO, or NO_x measurements exceed cut-points for each pollutant.

Table 1-89. Federal Three-Mode STE Comparison; 5 Percent E_c Fleet Average vs 5 Percent E_c for Each of Three CID Groups

Pollutant and Test Mode	Short Test Effectiveness (STE)$^{(a)}$	
	5% E_c Fleet Average	5% for Each of Three CID Groups$^{(b)}$
HC Idle in Drive	0.375	0.383
Idle in Neutral	0.338	0.339
CO Idle in Drive	0.562	0.605
Idle in Neutral	0.524	0.557
NO_x High Speed	0.310	0.341
Low Speed	0.301	0.291
Multiple Constituents$^{(c)}$ Idle in Drive	0.704	0.653
Idle in Neutral	0.597	0.592
Best Combination	0.663	0.648

(a) $STE = \frac{\%FF}{\%Eo + \%FF}$

(b) 150 CID and less
151 to 259 CID
260 and greater CID

(c) Car fails if any of HC, CO, or NO_x measurements exceed cut-points for each pollutant.

2. INTRODUCTION

2.1 BACKGROUND AND OBJECTIVES

With regard to compliance by vehicles and engines in actual use with the certification emission standards established for a vehicle at the time of its manufacture, the Clean Air Act of 1970 stipulates in Section 207(b):

> "If the Administrator determines that
>
> (i) there are available testing methods and procedures to ascertain whether, when in actual use throughout its useful life ...., each vehicle and engine to which regulations .... apply complies with the emission standards of such regulations,
>
> (ii) such methods and procedures are in accordance with good engineering practices, and
>
> (iii) such methods and procedures are reasonably capable of being correlated with tests conducted under section 206(a)(1), then --
>
> (1) he shall establish such methods and procedures by regulation, and
>
> (2) at such time as he determines that inspection facilities or equipment are available for purposes of carrying out testing methods and procedures established under paragraph (1), he shall prescribe regulations which shall require manufacturers to warrant the emission control device or system of each new motor vehicle or new motor vehicle engine ... for its useful life."

Thus, there are the essential requirements of "availability," "conformance with good engineering practices," and "reasonable correlation with certification test procedures" which must be met prior to the promulgation of regulations which impose the in-use warranty provisions of Section 207(b) upon the motor vehicle manufacturers.

The states of New York and New Jersey have developed short emission tests for potential use in inspection/maintenance (I/M) programs in their areas. The Clayton Manufacturing Company also developed a short test procedure for use in I/M programs. More recently, the EPA has developed short tests similar to those of New York, New Jersey, and Clayton. Thus, there are a number of tests "available" to determine the exhaust emissions of in-use vehicles; these test methods and procedures "conform with good engineering practices" in that they utilize well-recognized emission-measurement equipment and techniques.

These tests are "short" in duration (approximately 3 to 5 minutes) in order to (a) minimize the inconvenience of the motoring public (and thereby maximize cooperation), and (b) minimize capital costs of inspection stations by maximizing the number of vehicles a given facility could test. They have been structured for "simplicity" in order to (a) reduce the potential for procedural errors, and (b) to reduce test costs. As a result, all such tests require that the vehicle be tested in a "hot" condition; i.e., at its normal operating temperature.

There remains the requirement to demonstrate "reasonable correlation with certification test procedures;" i.e., with the Federal Test Procedure (FTP) used in the certification of new motor vehicles. An initial evaluation of the degree of "correlation" between five short tests (STs) and the FTP was previously conducted (Ref. 1) utilizing test data from a 40-car catalyst-equipped experimental vehicle fleet and a 147-car in-use 1974 model year vehicle fleet. Based on the results of that evaluation, two of the five STs were selected by EPA for further test and evaluation in a three-city, 300-car, 1975 model year vehicle fleet. The present study was performed, therefore, to analyze the resultant emission data from the short tests and FTP tests of this 300-car fleet to determine the degree of "correlation" between the ST and FTP test results. The same computational and statistical analysis techniques developed in the initial evaluation (Ref. 1) were used in the present study.

2.2 STUDY SCOPE

The basis for the analyses was ST and FTP data from three 100-vehicle fleets located in the following cities:

Chicago, Illinois
Houston, Texas
Phoenix, Arizona

Each of the 1975 model year vehicles was tested by the FTP and the following STs:

Federal Short Cycle
Federal Three Mode

For the undiluted exhaust type test (Federal Three Mode), garage-type instruments were used to record HC and CO measurements. Garage-type instruments were used to simulate the working environment of a typical automotive garage or a large-scale vehicle testing station. All the NO_x readings were made with laboratory analyzers due to the unavailability of an appropriate garage-type NO_x instrument.

2.3 METHOD OF APPROACH

The primary thrust of the work performed under this contract was statistical in nature. Two complementing methods were employed to assess Section 207(b) correlation -- a conventional correlation analysis and a contingency table analysis. The conventional correlation analysis addresses the question of direct relatability between the ST and the FTP by examining the relationships present in the data. The results are of great usefulness in indicating the extent to which each ST tends to track the FTP. The contingency table analysis addresses the relatability of ST and FTP on a pass-or-fail level. Each data point is examined, and a determination is made as to whether the auto passed or failed the FTP and passed or failed the ST. Thus, errors of commission (E_c), errors of omission (E_o), correct passes by each test (PP), and correct fails by each test (FF) are identified. Hence, the technique allows for the study of the tradeoffs between errors and correct identifications.

The conventional correlation analysis, being purely an analysis of the data, does not permit policy decision as a variable or parameter. Contingency table analysis, on the other hand, permits the integration of policy decision in that it provides for the determination of the ST pass/fail cut-points. One important method reflecting impact to policy is that of the method of bounded errors of commission. In this scheme, limits are set on the maximum permissible percentage of errors of commission, and the ST cut-points are selected to yield minimum errors of omission within this constraint. This analysis permits a direct answer to the question, "For a given permissible level of errors of commission, what level of errors of omission is associated with a given test, and with what impact on air quality (inferred from the percentage of FF and E_o vehicles)?"

These two methods of analysis, each representing different interpretations of Section 207(b) correlation, were applied to both the full 300-vehicle fleet and to each 100-vehicle city fleet.

3. TEST CHARACTERISTICS AND FLEET COMPOSITION

In this program, two short tests (STs) and the 1975 Federal Test Procedure (FTP) were performed on three 100-vehicle test fleets. This section defines the two STs and describes the composition of the test fleets.

3.1 SHORT TESTS

3.1.1 General

Two classes of STs were involved, and these may be categorized as (1) modal or volumetric and (2) as driving trace or CVS. Both sets of nomenclature are used in this report, depending upon the aspect of the test structure that is pertinent to the discussion. In the modal tests, the test technician operates the vehicle on a dynamometer at a fixed vehicle speed and dynamometer load, or at idle. The vehicle tailpipe exhaust is sampled directly, and the concentration of each pollutant is measured and recorded in percent, or in parts per million, of the undiluted exhaust. One modal ST was used, the Federal Three Mode. The Federal Three Mode ST has high-speed, low-speed, and idle modes. The idle mode can be conducted in two ways, (1) idle with transmission in drive (automatic transmission only), or (2) idle in neutral (automatic and manual transmissions).

For the second class of ST, the test technician drives the car on the dynamometer in accordance with a prescribed driving pattern on a driving trace. The vehicle exhaust is diluted by the constant volume sampling (CVS) procedure, and a single sample bag of diluted exhaust is collected for the whole ST. The dilute sample is analyzed and the results usually expressed in grams per mile. This procedure requires the same equipment, sampling procedure, and analytical equipment as the Federal Test Procedure (FTP) used in the certification of new vehicles. The difference is that the driving trace for the ST is much shorter and simpler. The CVS-type ST used was the Federal Short Cycle.

Both classes of ST involved approximately two or three minutes of driving time on the dynamometer, and both STs were performed with the engine at its normal operating temperature; i.e., hot tests.

The HC and CO content of the exhaust gas in the volumetric tests was measured by garage instruments, a lower-cost, lower-accuracy and precision instrument of the type currently in use by many automotive service stations for routine diagnostic work. The structure of each test is given below.

3.1.2 Short Test Definition

3.1.2.1 Federal Three Mode

The Federal Three Mode uses dynamometer loadings simulating the average power that occurs at the appropriate speeds in the FTP where the vehicle is accelerating (decelerations are not included). The speed and dynamometer loadings for the high-speed, low-speed, and idle test modes are shown below.

Vehicle Weight Class, lb	Transmission	High Speed Mode		Low Speed Mode		Idle Mode
		Speed, mph	Load, hp	Speed, mph	Load, hp	
Up to 2500	In lower gear for 30-mph test (3rd gear)	50	21	30	9	Automatic transmission in neutral
2501 to 3500	Drive or high gear	50	26	30	12	
3501 to 4500	Drive or high gear	50	31	30	15	
Above 4500	Drive or high gear	50	36	30	18	

3.1.2.2 Federal Short Cycle

The Federal Short Cycle was derived from the FTP. Accelerations and decelerations are representative of those encountered in the FTP, and average speed is nearly the same as the three-bag FTP driving cycle (21.70 mph and 21.27 mph, respectively).

This is a nine-mode, 125-sec CVS test that follows the driving schedule shown below and plotted in Figure 57 in the Appendix.*

Mode	Time in Mode, sec
0 - 16 mph acceleration	6
16 - 29 mph acceleration	23
29 mph cruise	10
29 - 37 mph acceleration	18
37 - 42 mph acceleration	4.5
42 - 37 mph deceleration	2.5
37 - 20 mph deceleration	32
20 - 0 mph deceleration	7.5
Idle	21.5
	125.0

The test does not include engine startup or shutdown. The dynamometer loadings follow the procedure as required for the FTP.

3.2 TEST FLEET COMPOSITION

3.2.1 Types of Cars

All 300 vehicles were 1975 model year vehicles representing a typical cross-section of that model year with regard to manufacturer (domestic and foreign), vehicle size (weight), engine size (displacement and number of cylinders), fuel system type, transmission type, and emission control system type. Tables 1 through 13 in the Appendix list cross-tabulations of specific features of the vehicle fleet in the following context.

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*Figure and table numbers refer to figures and tables contained in the Appendix.

Cross-Tabulation Feature	Table Number*
No. of cylinders vs engine displacement	1
Inertia test weight vs engine displacement	2
Emission control system vs engine displacement	3
Inertia test weight vs emission control system	4
Fuel system vs emission control system	5
Fuel system vs inertia test weight	6
Fuel system vs engine displacement	7
Transmission vs engine displacement	8
Transmission vs inertia test weight	9
Manufacturer vs engine displacement (all 3 cities)	10
Manufacturer vs engine displacement (Chicago)	11
Manufacturer vs engine displacement (Houston)	12
Manufacturer vs engine displacement (Phoenix)	13

Engine displacement was subdivided into three sizes:

a. 150 cubic inches displacement (CID) or less
b. 151 to 259 CID
c. 260 or more CID

Inertia test weight breakdown was limited to four categories:

a. 2500 lb or less
b. 2501 lb to 3500 lb
c. 3501 lb to 4500 lb
d. 4501 lb or greater

Emission control system description was limited to the use or non-use of oxidation catalysts and/or secondary air injection.

Fuel system type description refers to the use of either carburetion or fuel injection.

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*Table numbers refer to tables contained in the Appendix.

Transmission type refers to use of manual versus automatic transmissions.

3.2.2 Prior Use

At the time of receipt of these vehicles by the testing laboratory (Automotive Testing Laboratories, Inc.), the odometer readings ranged from less than 100 to 44,000, with an average of 8,390. Specific vehicle use patterns, in terms of city driving vs highway driving, were not quantified. The type and extent of vehicle and emission system maintenance were similarly undefined. It was assumed that the use and state-of-maintenance characteristics of this large test sample (300 vehicles from three different locations) would be adequately representative of the 1975 model year vehicle population.

4. STATISTICAL SCREENING AND CORRELATION ANALYSES

4.1 DISCUSSION OF METHODOLOGY

In studying the degree of correlation that exists between a particular short test (ST) and the Federal Test Procedure (FTP), a major concern is the variability in the correlation with vehicle population characteristics. That is, it is important to know which classes of vehicles, if any, show inadequate ST/FTP correlations. Thus, correlations on individual groupings of the data were assessed. In addition to assessing differences in correlation, differences in group means and standard deviation were also reviewed. Thus, in presenting the results of the analyses, means, standard deviations, and correlation coefficients were computed for each group of interest. Statistical tests of significance were performed as discussed below.

4.1.1 Conventional Correlation Analysis

A conventional correlation analysis includes the calculation of the sample correlation coefficient r, and an α-percent confidence interval for the population correlation coefficient ρ, on paired observations. Letting (x_i, y_i) $i = 1, ----, N$ denote the observations, r is defined by

$$r = \frac{\sum_{i=1}^{N} (x_i - M_x)(y_i - M_y)}{S_x S_y} \qquad (4\text{-}1)$$

where M_x, S_x and M_y, S_y are the mean and standard deviation of the observations x_i and y_i, respectively. An α-percent confidence interval is given by $(r-, r+)$, where the probability that the interval covers ρ is $\alpha/100$. For the 95 percent interval used in this study

$$r\pm = \tanh\left(z \pm \frac{1.96}{\sqrt{N-3}}\right) \qquad (4\text{-}2)$$

where $z = 1/2 \ln (1 + r/1 - r)$, (Fisher's Z statistic, Ref. 2).

The sample correlation coefficient is used as the prime quantitative measure of relatability. The closer r is to 1, the better the relation. A lack of relationship is indicated by $r = 0$. Negative r indicates an inverse relation between the observations, i.e., if one observation is high, the other is low, and vice versa. The confidence interval is viewed as reflecting the sensitivity of the calculations to the data. The wider the interval, the less predictable is the correlation coefficient and, hence, the relatability.

4.1.2 Statistical Tests of Significance

The ST/FTP correlation was classified as statistically deficient if the 95 percent confidence interval, given by equation (4-2), contains the value zero. Statistically, the computed value of r cannot be distinguished from zero due to the existing variability in the data.

To test for statistical differences in group means, a classical F-test for equality of group means was performed (Ref. 3). Both the computed F-value and the level of significance were reported. The level of significance can be interpreted as the probability of making an error when deciding to reject the hypothesis of equality.

To test for statistical differences in group standard deviations, Bartlett's test for homogeneity of group variances was performed, (Ref. 3). Both the computed statistic and the corresponding level of significance were reported.

Tables* 20a, 20b, and 21 provide excellent examples to illustrate the procedure. Table 20a shows the FTP means and standard deviations for each pollutant on each city group. In examining these means and standard deviations, differences in the values from group to group are quite noticeable. The results of F-tests and Bartlett's tests are shown in Table 20b (note that the significance tests were also performed on the logarithms of the FTP data). Thus, the differences in mean CO would be attributed to statistical variations, unless one is willing to accept a 20 percent chance of error in attributing the differences to differences in the cities. However, significant differences in variance do occur for HC and CO, and these differences can be attributed to systematic differences in the data from Chicago, Houston, and Phoenix. These findings are repeated with varying levels of significance for an analysis of the logarithms of the data.

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*Table numbers refer to tables contained in the Appendix.

Table 21 shows the ST/FTP constituent correlation coefficients for both STs using the pooled fleet of 300 vehicles. The coefficients were computed for each constituent and the logarithm of each constituent. The NO_x correlation for the Federal Three-Mode idle in neutral (0.11) and in drive (0.12) are statistically deficient and are noted as deficient with an asterisk. All the other coefficients in Table 21 are statistically significant, which means that they are statistically distinguishable from zero with 95 percent confidence. Whether the significant coefficients are high enough to be of practical value is a judgmental matter.

4.2 RESULTS FOR ALL THREE CITIES COMBINED

Preliminary analyses were made of the ST data. Means and variances were tested for homogeneity between cities and between engine displacement groups. Tables 14 and 15 give the results for the Federal Short Cycle by city and engine displacement, respectively. The Federal Three-Mode results are shown in Tables 16 and 17 for city and engine displacement grouping, respectively.

The effect of vehicle mileage was also investigated. The vehicles were grouped into those with 4000 miles or less and those with more than 4000 miles. Tables 18 and 19 show significant differences between the groups in their FTP means and standard deviation, and their ST/FTP correlation coefficients, respectively.

The results of an analysis of city effects are given in Tables 20, 21, 22, 23, 24. The differences in mean and standard deviations are addressed in Table 20, whereas the correlation coefficients are reported in Tables 21 through 24 for the pooled fleet (300 vehicles) and the individual city fleets (100 vehicles each).

An analysis to determine the effects of engine displacement, inertia test weight, emission control system, fuel system, transmission type, and manufacturer was performed on the pooled fleet of 300 vehicles. The table numbers for both STs correspond to the following statistics spectrum:

	Table Number		
For the Effects of	FTP Mean and Standard Deviations	Tests of Significance	ST/FTP Correlation Coefficients
Engine Displacement	25a	25b	26
Inertia Test Weight	27a	27b	28
Emission Control System	29a	29b	30
Fuel System	31a	31b	32
Transmission Type	33a	33b	34
Manufacturer	35a	35b	36

Additionally the ST/FTP correlation coefficients on each manufacturer's vehicles within an engine displacement group were computed. These results for both STs are shown in Tables 37, 38, and 39 for the 150 CID and less, 151 to 259 CID, and 260 CID and greater engine groups, respectively.

4.3 RESULTS FOR INDIVIDUAL CITY FLEETS

An analysis to determine the effects of engine displacement, inertia test weight, emission control system, fuel system, transmission type, and manufacturer was performed on the individual city fleets of

100 vehicles each. The Chicago fleet numbers, for both STs, correspond to the following statistics spectrum:

For the Effects of	Table Number		
	FTP Mean and Standard Deviations	Tests of Significance	ST/FTP Correlation Coefficients
Engine Displacement	40a	40b	41
Inertia Test Weight	42a	42b	43
Emission Control System	44a	44b	45
Fuel System	46a	46b	47
Transmission Type	48a	48b	49
Manufacturer	50a	50b	51

For the Houston fleet the Table correspondence is:

For the Effects of	Table Number		
	FTP Mean and Standard Deviations	Tests of Significance	ST/FTP Correlation Coefficients
Engine Displacement	52a	52b	53
Inertia Test Weight	54a	54b	55
Emission Control System	56a	56b	57
Fuel System	58a	58b	59
Transmission Type	60a	60b	61
Manufacturer	62a	62b	63

For Phoenix the table number correspondence is given by:

For the Effects of	Table Number		
	FTP Mean and Standard Deviations	Tests of Significance	ST/FTP Correlation Coefficients
Engine Displacement	64a	64b	65
Inertia Test Weight	66a	66b	67
Emission Control System	68a	68b	69
Fuel System	70a	70b	71
Transmission Type	72a	72b	73
Manufacturer	74a	74b	75

4.4 DISCUSSION OF RESULTS

The HC Federal Short Cycle/FTP correlation coefficient varies considerably between cities. It is 0.88 in Chicago, 0.91 in Houston, and 0.45 in Phoenix. This non-uniformity in the values of the correlation coefficient has been attributed in part to city differences in the FTP measurements. Vehicles 5520 and 5524 in Phoenix had extraordinarily high (relative to remaining data) HC accumulation in bag 1 of the FTP, which is the cold start portion of the FTP. This resulted in a high FTP composite. These vehicles had comparatively low Federal Short Cycle readings for the high FTP values. Although these vehicles were identified as having anomalous readings, they were not discarded for any of the subsequent analyses.

5. CONTINGENCY TABLE ANALYSES

5.1 DISCUSSION OF METHODOLOGY

The contingency table analysis technique was used to establish the short test (ST) pass-fail levels for each pollutant. The contingency table is defined in Table 133*, along with its associated parameters. A pictorial demonstration of its application to a given data set is shown in Figure 58. It can be seen that, for a given data set, part of the analysis is concerned with the criteria used to select the ST cut-points. In this regard, the bounded errors of commission method was used extensively to establish trends for the variations in E_c, E_o, FF, and PP. In this method, the ST cut-points are selected to minimize E_o while holding the E_c below a specified level. It thus permits a direct answer to the question, "For a given permissible level of E_c, what level of E_o is associated with the ST, and with what impact on air quality (inferred from number of FF and E_o vehicles)?" This method is illustrated in Figure 59. The policy decision is the maximum allowable E_c.

The Federal Test Procedure (FTP) levels used throughout the analyses were 1.5 grams/mile for HC, 15.0 grams/mile for CO, and 3.10 grams/mile for NO_x.

With regard to procedural technique, a bivariate normal or log-normal distribution model was fitted to a particular data set by incorporating the correlation coefficient, mean values, and standard deviations of the data set. The bivariate normal distribution is shown in Figure 60. The mathematical format of the log-normal distribution is identical to that shown in Figure 60 except the statistics and variables are in terms of the natural logarithm of the measurements. Figure 61 shows the pertinent probability equations used for predicting the table entries.

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*Table numbers refer to tables contained in the Appendix.

The ST cut-points were determined by using the model as determined from the data and by solving the equation in Figure 62. Once the cut-points have been established, the predicted table entries for each pollutant can be computed using the formulas shown in Figure 61.

Also determined in the contingency table analysis were the short test effectiveness and the short test rejection ratio. ST effectiveness is defined as:

$$\text{ST effectiveness} = \text{STE} = \frac{\%\ \text{FF for the short test}}{\%\ \text{FTP failures in same population}} \qquad (5\text{-}1)$$

$$= \frac{\%\ \text{FF}}{\%\ \text{FF} + \%\ E_o}$$

Thus, on this basis, the ST is always less effective than the FTP, in proportion to the percent of errors of omission (E_o) associated with a given ST, and the short test effectiveness (STE) value is a relative measure of the impact on air quality from ST implementation.

The short test rejection ratio (STRR), is defined as:

$$\text{STRR} = \frac{\%\ E_c + \%\ \text{FF}}{\%\ E_o + \%\ \text{FF}} \qquad (5\text{-}2)$$

The denominator of this ratio ($\%\ E_o + \%\ \text{FF}$) represents the percent of the vehicle population actually failing the FTP. The numerator ($\%\ E_c + \%\ \text{FF}$) represents the percent of the vehicle population failing the short test. Thus, the resultant ratio (STRR) is an indication to flag those situations where the implementation of a short test or test mode could result in a greater number of vehicles being failed than should be failed based upon FTP standards. Whereas the STE value is a measure of the relative impact of the use of the ST on air quality, the short test rejection ratio (STRR) value (which includes consideration of those E_c vehicles incorrectly identified by the ST as failing the FTP) can be considered a relative measure of the "fairness" of the ST to the vehicle manufacturer or vehicle size or class. For example, only when the STRR value exceeds one would the manufacturer be required to implement warranty procedures on a greater number of vehicles than he should have based upon the observed FTP failure rate.

In addition to analyzing each pollutant individually, an analysis was made for three-constituent tests, using the contingency table approach. In a three-constituent test, a car fails the ST if any of its HC, CO, and NO_x measurements exceed the previously determined cut-points. This test is applicable to the Federal Short Cycle and the individual modes of the Federal Three-Mode. A car fails the ST if any one of the modes fails on its three-constituent tests. A model for predicting population results was not available; hence the actual data was used along with pre-established cut-points to count the number of vehicles in each cell of the contingency table.

The computational procedure followed in determining the three constituent tests is shown in Figure 63. Note that the cut-point selection policy is applied at the pollutant level and not at the multiple-constituent test level. For example, the percent E_c is bounded for individual pollutants in the method of bounded errors of commission, and this bound can possibly be exceeded on a three-constituent test. In forming the three-constituent test contingency table, the following definitions apply:

Correctly passed (PP): Car passes the ST and the FTP
Correctly failed (FF): Car fails the ST and the FTP
Error of commission (E_c): Car fails the ST and passes the FTP
Error of omission (E_o): Car passes the ST and fails the FTP

where FTP or ST failure occurs if any one of the test constituents exceeds its respective cut-points. A car is counted once in forming the table and falls into one, and only one, of the above categories.

The "best" three-constituent test was formed by selecting those individual test modes for HC, CO, and NO_x for which the correlation coefficient was maximum. A typical example might by HC and CO at idle and NO_x at the high speed mode.

5.2 VARIANCE ESTIMATES

5.2.1 Short Test Cut-Points

The problem of estimating the ST cut-point, for a fixed FTP level, is analogous to estimating the quantiles of a distribution function (Ref. 4). Thus, the large sample standard deviation is given by

$$\left| \frac{1}{\frac{dp(y)}{dy}} \right|_{y = LS_o} \sqrt{\frac{\gamma(PF - \gamma)}{N}} \qquad (5\text{-}3)$$

where

PF = probability of passing the FTP

p(y) = probability of an error of commission for ST cut-point set at value y

γ = upper bound on probability of errors of commission

N = sample size or number of cars in the data set

LS_o = true cut-point for the population

As PF, p(y), and LS_o are unknown, they can only be approximated from the data. LS_o is, of course, approximated by the cut-point estimated from the data. PF is estimated on the percent passed by FTP divided by 100, p(y) is taken to be the locus of E_c versus cut-point and $dp(y)/dy|LS_o$ is taken as the derivative of the E_c versus cut-point curve evaluated at the cut-point of interest (LS_o). Equation (5-3) will be used to discuss variability of the predicted population.

For a fixed FTP level, the standard deviation of the estimated cut-point can be independently controlled by increasing the sample size. Once the sample size is fixed, this standard deviation varies inversely with the magnitude of the derivative of the E_c versus cut-point curve. Thus, in regions where the curve is steep, the variability of the predictions will be less than in regions where the curve is flat. Figure 64 illustrates the effect of the cut-point uncertainty on the other computed quantities of E_o and FF. It shows that the uncertainty in the predicted results increases with decreasing errors of commission bounds.

Standard deviations were calculated for each ST cut-point computed and are displayed herein as necessary.

5.2.2 Three-Constituent Test Percentages

For fixed ST and FTP cut-points, the cell counts in a 2 x 2 contingency table are binomially distributed when the observations are independent (Ref. 5). Since the ST cut-points are computed from data prior to forming the contingency table, there is statistical dependence between the ST cut-points and the resulting table. Hence, the binomial distribution will be an approximation to the true distribution. Thus, the approximate standard deviation is

$$\sqrt{\frac{X\,(100 - X)}{N}} \tag{5-4}$$

where

X = cell count in percent
N = total table count

This procedure was used to calculate the standard error of the estimates for the three-constituent test results reported herewithin. Table 104 in the Appendix lists the standard errors as a function of sample size and cell percentage.

5.3 SPECIFIC ANALYSES AND THEIR RESULTS

5.3.1 Analyses with Short Test Cut-Points Based Upon 300 Cars

Using the 300 car data set, ST cut-points for HC, CO, and NO_x were determined for various rates of commission errors. The differences between various stratum within the data set were assessed by predicting the contingency entries for the strata using the above pre-established cut-points. The effects of varying engine displacement, inertia test weight, emission controls, carburetion, transmission, and manufacturer were investigated in this manner.

The results are presented in graphical and tabular form in the Appendix and are referenced in the discussions to follow. The results are presented first by individual constituent, followed by the results of multiple constituent tests, and, finally, the results indicating the effects of engine displacement, inertia weight, emission systems, carburetion, transmission, and manufacturer are given.

5.3.1.1 Hydrocarbon Emissions

The variation of E_c, E_o, and FF as a function of HC cut-point was determined for each ST. The results for the pooled fleet, using the Federal Short Cycle and the Federal Three-Mode, are shown graphically in Figures 1 and 17 to indicate the general nature of the trade-offs available.

Shown in Figures 4, 7, and 10 are the Federal Short Cycle results for each individual city fleet (100 vehicles each). The corresponding Federal Three-Mode results are displayed in Figures 20, 23, and 26. Note, however, that the cut-points used in these figures were determined by using the pooled fleet of 300 vehicles.

Table 76 summarizes the results for both STs for the pooled fleet and individual city fleets at the specific E_c analysis value of 5 percent. This value was used in the analysis to set HC ST cut-points based on the total pooled fleet population. These same numerical cut-points were then used in subsequent contingency analyses on an individual city and test mode basis. As a consequence, the resultant actual E_c values for the individual cities or test modes vary from the 5 percent E_c value for the pooled fleet due to differences in observed emission characteristics between the pooled fleet and the individual city fleets. Also shown in Table 76 are the effectiveness values (STE).

5.3.1.2 Carbon Monoxide Emission

The variation of E_c, E_o, and FF for the pooled fleet as a function of CO cut-point are shown for the Federal Short Cycle and the Federal Three-Mode in Figures 2 and 18, respectively. The individual city fleet results are shown in Figures 5, 8, and 11 for the Federal Short Cycle and Figures 21, 24, and 27 for the Federal Three-Mode. Table 77 summarizes the results for both STs for the pooled fleet and individual city fleets at the E_c analysis value of 5 percent.

5.3.1.3 Oxides of Nitrogen Emission

The pooled fleet variations of E_c, E_o and FF as a function of NO_x cut-point are shown in Figures 3 and 19 for the Federal Short Cycle and the Federal Three-Mode, respectively. The results for the individual city fleets are shown in Figures 6, 9, and 12 for the Federal Short Cycle and Figures 22, 25 and 28 for the Federal Three-Mode. Table 78 summarizes the results for both ST for the pooled fleet and individual city fleets at the E_c analysis value of 5 percent.

5.3.1.4 Multiple Constituent Tests

The variation of actual E_c, E_o, and FF as a function of predicted E_c are shown for the three-constituent Federal Short Cycle in Figures 13, 14, 15, and 16 for the pooled fleet and individual city fleets, respectively. The corresponding Federal Three-Mode idle in drive mode and best mode three-constituent results are shown in Figures 29, 30, 31, and 32 for the pooled fleet and individual city fleets respectively. The best mode refers to the combination of the best individual test modes: the idle-in-drive for HC and CO discrimination and the high speed for NO_x. Table 79 shows the three-constituent results for both ST for the pooled and individual city fleets at the E_c analysis value of 5 percent.

5.3.1.5 Effects of Vehicle Characteristics

The variation of E_c, E_o, and FF with engine displacement, inertia test weight, emission control system, fuel system, transmission and manufacturer were individually determined for the E_c analysis value of 5 percent. The results are presented for both ST in Tables 80 through 103 and correspond to the following constituent spectrum:

For the Effects of	Constituent Table Number			
	HC	CO	NO_x	Three Constituents
Engine Displacement	84	85	86	87
Inertia Test Weight	80	81	82	83
Emission Control System	88	89	90	91
Fuel System	92	93	94	95
Transmission Type	96	97	98	99
Manufacturer	100	101	102	103

5.3.1.6 Comparison of Short Test Cut-Points

Table 105 summarizes the variation of the Federal Short Cycle cut-point value for each emission constituent required to result in a 5 percent E_c rate in each individual city for the pooled 300-vehicle fleet. Table 106 summarizes similar cut-point variations for the Federal Three-Mode ST (idle in drive for HC and CO, and high speed in NO_x).

5.3.2 Analyses with Short Test Cut-Points Based Upon Engine Displacement

An additional contingency table analysis was made wherein the ST cut-points were determined for each CID class and were based on a

5 percent E_c rate for the CID class alone, not the pooled 300-vehicle fleet as in the results presented in Section 5. 3. 1. The results of this investigation are reported below.

5. 3. 2. 1 150 CID and Less Displacement Group

Tables 107 through 110 present the results of this analysis for both ST while showing the variation in E_c, E_o and FF by manufacturer. Tables 121 through 124 show the variation in E_c, E_o and FF by city. The analysis was made for an E_c value of 5 percent and the tables correspond to the following constituent spectrum:

For the Effects of	Constituent Table Number			
	HC	CO	NO_x	Three Constituents
Manufacturer	107	108	109	110
City	121	122	123	124

5. 3. 2. 2 151 to 259 CID Group

Tables 111 through 114 show the variation in E_c, E_o, and FF by manufacturer for both ST while Tables 125 through 128 show the results by city. The following correspondence shows the table numbers for the constituent spectrum:

For the Effects of	Constituent Table Number			
	HC	CO	NO_x	Three Constituents
Manufacturer	111	112	113	114
City	125	126	127	128

5.3.2.3 260 and Greater CID Group

Tables 115 through 118 and Tables 129 through 132 show the variation of E_c, E_o, and FF for both ST as a function of manufacturer and city according to the following correspondence:

For the Effects of	Constituent Table Number			
	HC	CO	NO_x	Three Constituents
Manufacturer	115	116	117	118
City	129	130	131	132

5.3.2.4 Comparison of Short Test Cut-Points

Tables 119 and 120 summarize the variation of cut-point value for each emission constituent required to result in a 5 percent E_c rate in individual displacement group and for the pooled 300-vehicle fleet for the Federal Short Cycle and the Federal Three-Mode, respectively.

6. 207(b) IMPLEMENTATION SIMULATION ANALYSES

6.1 OBJECTIVES AND APPROACH

The objective of this effort was to assess the effectiveness of a 207(b) program in reducing total emissions from light-duty vehicles as characterized by the data collected on the 300 1975 model year cars. Engineering judgment was to be used where firm data was lacking.

A computer program was developed which follows the logical flow chart shown in Figure 65.* The purpose of the computer program was to simulate the implementation of a 207(b) program on a specific fleet of vehicles, the "controlled fleet", and compare the emission results to an uncontrolled fleet, originally identical, which deteriorates without the influence of a mandatory 207(b) program. The comparison was made over a 50,000 mile period for each fleet, and the effectiveness of the 207(b) program was assessed annually.

The two simulated fleets were each divided into three mutually exclusive groups based upon engine displacement: 150 CID and less, 151 to 259 CID, and 260 CID and greater. Existing 300-car data was used to establish a distribution model for the emission values of the three regulated pollutants at the mean mileage for each displacement group. This distribution model was then used to stochastically generate the two identical fleets of vehicles with statistical attributes similar to the 300-car data set.

The controlled fleet was aged under the influence of a mandatory inspection/maintenance program which included an annual inspection of each vehicle, mandatory maintenance of those vehicles failing the inspection, and simulated deterioration based on mileage accumulation models. The uncontrolled fleet was aged using deterioration models based on mileage accumulation. The deterioration models all assumed linear deterioration with accumulated mileage.

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*Figure and table numbers refer to tables and figures contained in the Appendix.

The existing 300-car data set was used to establish the short test (ST) inspection pass-fail levels. Two methodologies in selecting the levels were examined. The first method, designated the 207(b) approach, established pass-fail levels for each engine displacement group at a 5 percent error of commission rate for each pollutant. The second method designated the I/M approach, established, for each pollutant, a single pass-fail level which applied to all groups. The I/M pass-fail levels were determined using a 33 percent total failure rate with a three constituent test.

Because of uncertainties in the areas of deterioration rates and maintenance effectiveness, a limited sensitivity analysis was performed by using several different maintenance models and by varying many of the program input parameters. This provided visibility into the variability of the results and identified the most sensitive components of the analysis program.

6.2 PROGRAM COMPONENTS

In the sections below, the following components of the simulation (see Figure 65) are discussed:

6.2.1 Initializations (of vehicle mix, mileage, etc.)
6.2.2 Generation of Fleets (vehicles to be tracked)
6.2.3 Emission Inspection Model
6.2.4 Vehicle Maintenance Models
6.2.5 Mileage Accumulation and Deterioration Model
6.2.6 207(b) Effectiveness Calculations

6.2.1 Initializations

Given the distributional parameters of the 300-car data, the use-in deterioration factors from the Emission Factors Program (EFP) were applied to these parameters to establish a distribution of fleet emissions at the average mileage equivalent to the first inspection point (e.g., 17,500 miles). Linear deterioration was used to accomplish this initialization.

6.2.2 Generation of Fleets

The adjusted distribution model from the initialization component was used to stochastically generate a fleet of vehicles (e.g., 3000 cars). A tri-variate log-normal probability distribution model was used to produce, for each vehicle, values of the HC, CO, and NO_x emission rates in grams/miles. The values represent the emission rates that would be measured by a Federal Test Procedure (FTP) on the particular vehicle. The statistical properties of the simulated fleet and the 300-car data set were quite similar. This set of simulated vehicles was tracked simultaneously with and without the influence of a mandatory inspection/maintenance program.

6.2.3 Emission Inspection Model

6.2.3.1 General

The model is composed of two components which are executed sequentially for each vehicle of the controlled fleet. The first component, measurement, consists of generating the ST measurements, given the emission rates which characterize the vehicle. Once the measurements for HC, CO, and NO_x have been noted, the second component is entered which is designated as the inspection component. The inspection component consists of determining whether the vehicle passes or fails the ST and classifies the vehicle as an FF, E_c, E_o, or PP.

6.2.3.2 Measurement Component

The ST measurements for the three regulated pollutants of each vehicle were generated stochastically using a conditional tri-variate log-normal probability model, the parameters of which were determined from the original 300-car data. Thus, given the FTP emission rates which characterize the vehicle, three ST emission values (one per pollutant) were generated to simulate the effects of the measurement procedure and testing equipment. In this manner, the statistical properties inherent in the 300-car data were approximated by the model and data generated which was characteristic of the observed 300-car ST/FTP data. The pertinent mathematical equations are contained in "An introduction to Multivariate Statistical Analysis," by T.W. Anderson, (Ref. 6).

6.2.3.3 Inspection Component

The ST measurement generated in the above component and the FTP emission rates are used to classify the vehicle. The vehicle fails the ST inspection and the FTP inspection if any one of the three pollutant measurements exceed their respective ST cut-points. The vehicle is thus classified according to the following:

Type	Inspection Results
PP	Passes ST and FTP
FF	Fails ST and FTP
E_c	Fails ST, passes FTP
E_o	Passes ST, fails FTP

This classification, the FTP emission rates, and the ST measurements are considered as pertinent data for the various alternative maintenance models, and, hence, were carried through to the vehicle maintenance model and the deterioration model.

6.2.4 Vehicle Maintenance Models

6.2.4.1 General

The results of the inspection model were used to select a maintenance policy for each vehicle individually. The general philosophy of the maintenance model was to perform corrective maintenance on all those vehicles failing the ST by adjusting the FTP failure rates on each emission in accordance with some pre-established rules or methods. If a vehicle passes the ST, no such maintenance action was taken. Specifically, if the vehicle is classified as an E_c or FF vehicle, the FTP emission rates are adjusted to reflect the effect of corrective maintenance. If the vehicle is classified as a PP or E_o vehicle, the FTP emission rates are left undisturbed. Several methods of adjusting the FTP values were investigated and are discussed in the following sections.

6.2.4.2 Version 1: HC and CO Coupled with a Lower Bound

For vehicles failing the ST, the following checks and adjustments were made in the order presented:

a. NO$_x$ Check and Adjustment. If NO$_x$ exceeded the federal standard of 3.1 grams per mile, then the vehicle's FTP rate of NO$_x$ emission was adjusted to 3.1 grams per mile. If NO$_x$ was below 3.1 grams per mile, then the vehicle's FTP rate of NO$_x$ emission was undisturbed.

b. CO Check and Adjustments. If CO exceeded the federal standard of 15.0 grams /per mile, then the FTP CO rate of emission was adjusted to 15.0 grams per mile, and the FTP HC rate of emission was adjusted as follows:

$$HC_{adj} = MAX\left(1/2\ HC_{std}\ ;\ HC_{old} \times \frac{CO_{adj}}{CO_{old}}\right) \qquad (6\text{-}1)$$

where

HC_{adj} = adjusted value of HC

HC_{std} = HC federal standard, 1.5 grams per mile

HC_{old} = HC before adjustment

CO_{adj} = adjusted value of CO which is 15.0 grams mile

CO_{old} = CO before adjustment

After these adjustments, the vehicle was checked to see if HC exceeded its federal standard.

If CO was below its standard, then the vehicle was checked for HC failing its standard.

c. HC Check and Adjustments. If HC exceeded the federal standard of 1.5 grams per mile, then HC was adjusted to 1.5 grams per mile, and CO was adjusted in accordance with Equation (6-1) where HC and CO have been interchanged. If HC was below its standard, then HC and CO were left undisturbed.

The adjustment of NO_x is independent of the values of HC and CO. However, when either CO or HC is adjusted the other is adjusted with the same percentage reduction. This naturally couples the maintenance of CO and HC. In any event the adjusted values are not allowed to be less than one-half the value of their respective standard.

6.2.4.3 Version 2: HC, CO, and NO_x Independently Adjusted to the FTP Standard

For vehicles failing the ST, each pollutant was checked individually. Those pollutants exceeding their respective FTP standard were adjusted to their FTP standard. If a pollutant was below its standard, it was left undisturbed. Thus pollutants not exceeding their standard were not affected by those pollutants which did exceed their standards.

6.2.4.4 Version 3: HC, CO, and NO_x Independently Adjusted to the Short Test Standard

For vehicles failing the ST, each pollutant was checked individually. Those pollutants exceeding their respective ST standard and their FTP standard (FF vehicles), were adjusted to an FTP value in grams per mile equivalent to their ST standard. Those pollutants exceeding their respective ST standard, but falling below their FTP standard (E_c vehicles), were adjusted to their FTP standard. If a pollutant was below its ST standard, it was left undisturbed and these pollutants were not affected by those pollutants failing their ST standards.

6.2.4.5 Overview of Maintenance Models

Maintenance options and adjustment procedures used in each version of the maintenance model are shown in Table 134 of the Appendix.

6.2.5 Mileage Accumulation and Deterioration Model

6.2.5.1 General

In this model the general effects of age and wear were simulated by deteriorating the emission rates from their value at the last inspection and maintenance point to the next I/M point. Several alternative deterioration concepts are available to be incorporated into such a model. Three of these important deterioration types are discussed below.

6.2.5.2 Deterioration Based Upon Certification Data

The deterioration factors estimated from the certification program represent somewhat optimal conditions with respect to maintenance, driving habits, and time span of mileage accumulation. The maintenance is, of course, performed promptly in accordance with the manufacturers' specifications and is most likely of the highest quality. The driving of the durability vehicles is performed by professional drivers who probably inflict less abuse on the engine than the average driver. The mileage is accumulated in a somewhat optimal manner. Typically, the vehicle would be operated approximately four hours at a time, twice a day. The total elapsed time is typically on the order of three months, thus eliminating age and seasonal effects.

Hence, deterioration based on certification data may not be representative of typical deterioration within the population of in-use vehicles and is probably not representative of any large segment of the in-use vehicle population. However, it can be interpreted as an idealized extreme.

6.2.5.3 Deterioration Based Upon Emission Factors Program Data

The deterioration factors estimated from the Emission Factors Program (EFP) represent typical deterioration of vehicles owned and operated by the public. Maintenance habits, driving characteristics, and time span of mileage accumulation are all quite variable from vehicle to vehicle and are difficult effects to isolate. Thus, the deterioration rates are interpreted as being based on the average of maintenance habits, driving characteristics, and time span of mileage accumulation. No attempt has been made to isolate the effects upon deterioration of these and other important variables. Thus, these deterioration rates were taken as representative of voluntary maintenance on in-use vehicles.

6.2.5.4 Deterioration Based Upon Near-Term Effects of Maintenance

The disadvantage common to the two above types of deterioration is that they are long-term in effect and apply over a large range in mileage, i.e., 50,000 miles. However, maintenance requirements are considerably more frequent, which suggests the presence of a short-term and possibly more rapid deterioration effect. In fact, studies (Refs. 7 and 8) have shown that the effect of maintenance is short-lived, six months to a year, with respect to emission reductions. This is an important effect which would support an optimistic position on inspection and maintenance.

6.2.5.5 Specific Models Employed

6.2.5.5.1 Uncontrolled Fleet

Deterioration effects on this fleet are based upon linear models with mileage accumulation. The vehicles are classified into two groups:

a. Vehicles passing the FTP
b. Vehicles failing the FTP

Certification deterioration factors were applied to vehicles in group a, and EFP factors were applied to vehicles in group b. The actual values of the deterioration factors are shown in Table 135.

6.2.5.5.2 Controlled Fleet

Deterioration effects on this fleet are based upon piecewise linear models with mileage accumulation. The vehicles are classified into four groups (E_c, E_o, PP, and FF vehicles), with the following deterioration rates:

a. PP Vehicles. Certification rates as shown in Table 135.

b. E_o Vehicles. EFP rates as shown in Table 135.

c. E_c Vehicles. Certification rates shown in Table 135. Deterioration occurs after the maintenance adjustments.

d. FF Vehicles. A maintenance effectiveness period is specified as an input to the simulation program. This period is the number of months (less than or equal to 12) required for the emissions to return to their value just prior to maintenance. After this period, if less than 12 months, the emissions are deteriorated according to the EFP rates as shown in Table 135. This situation is displayed in Figure 66.

6.2.6 207(b) Effectiveness Calculations

Program effectiveness was based upon total mass of pollutants emitted since the inception of the program, reported annually. For each pollutant the total grams emitted for each vehicle were calculated for the average mileage accumulations shown in Table 136. The total mass for each fleet is calculated by summing over each vehicle within the respective fleets. The effectiveness is then expressible as a percent change relative to the uncontrolled fleet.

6.2.7 Overview of Simulation Models

The initial values of the emission rates are established stochastically for each vehicle in the simulated fleets. Beyond this, the changes in emission rates of individual vehicles in the uncontrolled fleet are purely deterministic. However, the changes in emission rates and the sequence of events causing these changes are inherently stochastic for individual vehicles in the controlled fleet. This is due entirely to the stochastic behavior of the inspection model.

If a vehicle has been classified as an E_o or FF, then at least one pollutant exceeded its standard. Since the combined effects of maintenance and deterioration over one year leave the year's end emission value greater than or equal to the year's beginning emission value, a vehicle classified as an E_o or FF the previous year will be an E_o or FF the following year. For example, an FF one year will be an FF or E_o the following year and the probability of each is determined by the inspection model.

If a vehicle has been classified as an E_c or PP vehicle, then all of its emission rates were below the standards. An E_c vehicle, because of the maintenance method, will become an E_o or FF in the following year regardless of the rate of deterioration. A PP vehicle may be a PP, E_c, FF, or E_o vehicle the following year, depending on the rate of deterioration. If deterioration is rapid enough so that the vehicle fails the FTP in the following year, then the vehicle will be an FF or E_o. However, if deterioration is not enough to fail the vehicle on the FTP, then the vehicle will be an E_c or PP vehicle the following year.

These patterns, summarized in Figure 67, may not be realistic and should be further investigated with data from other sources such as Reference 8.

6.3 SIMULATION SCENARIOS AND RESULTS

6.3.1 General

With each case or scenario treated, many input parameters remained unchanged. For the current set of analyses these inputs were:

a. Mileage driving schedule as given in Table 136.

b. The 1975 FTP standards which were 1.5 g/mi HC, 15.0 g/mi CO, and 3.1 g/mi NO_x

c. Number of simulated vehicles in each fleet which was 3000 each.

d. The number of engine displacement groups which was three.

e. The vehicle mix which was 31.7 percent 150 CID and less, 18 percent 151 to 259 CID, and 50.3 percent 260 CID and greater.

f. Starting seed for the simulation.

g. Deterioration rates are given in Table 135.

h. Means and covariance matrices for the logarithm of FTP emissions for each engine group.

i. Means and covariance matrices for the logarithm of ST emissions for each engine group. The ST was formed using the best three constituent test of the Federal Three-Mode, i.e., HC and CO idle in drive, NO_x at the high speed, (the 151 to 259 CID group used NO_x at the low speed).

j. Cross-covariance matrices between the FTP and ST for each engine group.

These inputs generated an initial fleet with the characteristics shown in Table 137. The means and standard deviations shown in Table 137 have been corrected to reflect a sample with average mileage of 17,500 miles. Below are presented the individual cases which were simulated along with the additional inputs required and the results obtained.

6.3.2 Specific Scenarios and Their Results

6.3.2.1 Introduction

As previously indicated analyses were conducted to assess the effectiveness of a 207(b) program which establishes ST cut-points on the basis of engine family and an I/M program which establishes for the entire fleet a single ST cut-point for each pollutant. Each of these analyses included an analysis using each of the three maintenance models for three different maintenance effectiveness periods. The results, presented below, are grouped according to the type of program being simulated.

6.3.2.2 Simulation of 207(b) Programs

Shown in Table 138 are the ST cut-points used in the 207(b) analyses. The cut-points were computed from the 300-car data set by using a 5 percent E_c rate for each individual pollutant on each engine classification. For each version of the maintenance model analyzed, three maintenance effectiveness periods were used: 12 months, 9 months, and 6 months.

Tables 139 through 141 show the results of the 207(b) analyses. The FTP values equivalent to the ST cut-points are shown in Table 142. These rates were used in maintenance model version 3 as the levels to which emissions were reduced for maintained vehicles. The program efficiences were calculated by accumulating and comparing the total emissions from each fleet beginning at the first inspection point. Hence these efficiencies do not represent the full 50,000 miles of operation since the emission during the first year of the fleet population's life was not included in this computation.

6.3.2.3 Simulation of I/M Programs

Shown in Table 143 are the ST cut-points used in the I/M analyses. The cut-points were computed so that 33.33 percent of the original 300 vehicles would fail the ST. For each version of the three maintenance models analyzed, three maintenance effectiveness periods were used; 12 months, 9 months, and 6 months. Tables 144 through 146 show the results of the I/M analyses. The FTP values equivalent to the ST cut-points are shown in Table 147. These rates were used in maintenance model version 3 as the levels to which emissions were reduced for the maintained vehicles. The program efficiencies were calculated as explained above for the 207(b) analyses.

6.4 DISCUSSION AND CONCLUSIONS

The superiority of the 207(b) approach or the I/M approach cannot be determined from this set of analyses. Due to the method of selecting the I/M ST cut-points, (i.e., a 33.33 percent total ST failure rate), the error of commission rate for the I/M program is predicted at 2 percent for each pollutant on the total fleet. The 207(b) program, with a 5 percent E_c rate, produces higher ST total failures, 42.4 percent. This difference in total failures and in E_c rate, alone, will shown 207(b) to be more effective than I/M. This is substantiated by comparing the results shown in Tables 139 through 141 to the results shown in Tables 144 through 146. At a given E_c rate it is unclear which approach would be more effective.

For a 207(b) program the effects of the maintenance model and the period of effective maintenance are readily compared. These effects are discussed below for each pollutant.

> HC. For a fixed period of effective maintenance, verision 3 of the maintenance model had the lowest efficiencies with the efficiency of version 1 and 2 being equal. The phenomenon is thought to be due to the fact that the vehicles are maintained to lower FTP levels in versions 1 and 2 than in version 3.
>
> CO. For a fixed period of effective maintenance, version 1 had the highest efficiencies, and version 3 had the lowest efficiencies. The differences in the efficiency using version 2 and version 3 were less than 1 percent. Version 1 uses a coupled scheme for maintaining HC and CO, thus CO can benefit from improvements in HC which will produce higher CO efficiencies than an independent method of adjustment. The difference in efficiencies between versions 2 and 3 are attributed to the difference in the FTP values to which the vehicles were maintained.
>
> NO_x. For a fixed period of maintenance effectiveness, version 3 showed lower efficiencies than version 1 and 2 which are identical. Again this is attributed to the lower FTP maintenance levels in version 1 and 2.

For a fixed version of maintenance, program efficiencies decrease with decreasing periods of maintenance effectiveness for each pollutant. Intuitively, the quicker the erosion of maintenance, the less the impact of maintenance.

For a fixed maintenance effectiveness period and a fixed maintenance version, the efficiency of the program increases as the duration of the program increases. Although this behavior is expected, it has several important consequences. The earlier the program can be instituted, the greater the resulting benefit on air quality and the higher will be the program efficiency at 50,000 miles. Since emissions on controlled vehicles cannot be reduced to zero, the maximum program efficiency is less than 100 percent and can be approximated by allowing program duration to increase beyond the 50,000 mile limit. This maximum will still be dependent upon the time at which the program is established.

The behavior observed for 207(b) is likewise found in the I/M results, Tables 144 to 146. The only exception occurs for CO. For a fixed value of the maintenance effectiveness period, version 1 is highest and version 3 is lowest, as shown in the 207(b) results. However, the maximum difference between the CO efficiencies of version 2 and 3 is 4.9 percent, and the differences are consistent above about 2 percent. This is most likely due to the inverse relationship in the CO ST standard of the 207(b) simulation and the I/M simulation. Notice that for the 207(b) simulation the CO ST standards, in FTP units as shown in Table 142, decrease with increasing engine size. For the I/M simulation the CO ST standards, Table 147, increase with increasing engine size. This difference, taken with the fact that the 260 CID and greater engine class accounts for 50 percent of the total fleet, offers an explanation.

The following general comments are offered to aid the interpreter of these results and, hopefully, increase their utility. Program impact on air quality can be meaningfully measured on an annual basis or on a cumulative basis. The cumulative impact should probably be measured over the total life of the vehicle up to 50,000 miles. The efficiencies presented herein have been computed over the 17,500 to 50,000 mile segment of the fleet population's life. Thus the percent improvement in air quality on a cumulative basis will be lower than the above calculated efficiencies (with estimates running approximately 50 percent lower).

In any simulation, the interpreter of the results must realize that the properties and general behavior observed in the results are directly attributable to the simulator. Since simulation is based primarily on belief and secondarily on fact, the degree to which the results can be extrapolated is dependent upon the interpreter's belief in the underlying models used to construct the simulator. Sensitivity analyses can be used to increase the diversity of beliefs or models and hence reflect the sensitivity of the results to these underlying models.

A limited attempt at a sensitivity analysis was made during this study through the use of three models of maintenance and three periods of the effectiveness of maintenance. Although this provided a much needed diversity in models, there are many other different approaches to maintenance and deterioration which could be represented. One deficiency inherent in all three models of maintenance examined in the present analysis is that an E_c vehicle always is an FF or E_o vehicle the following year. This deficiency is traceable to the deterministic approach employed which can perhaps be eliminated through the use of stochastic maintenance models.

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Table 1. Cross Tabulation of Vehicles by Number of Cylinders and Engine Displacement – All Three Cities[a]

No. of Cylinders	Engine Displacement		
	150 CID[b] or Less	151 to 259 CID	260 CID or Greater
4	95	0	0
6	0	54	0
8	0	0	151

[a] 300 vehicles total

[b] CID = cubic inch displacement

Table 2. Cross Tabulation of Vehicles by Inertia Test Weight and Engine Displacement – All Three Cities

Inertia Test Weight Group (lb)	Engine Displacement			Total Number of Vehicles
	150 CID[a] or Less	151 to 259 CID	260 CID or Greater	
2500 or Less	49	1	0	50
2501 to 3500	46	46	27	119
3501 to 4500	0	7	91	98
4501 or Greater	0	0	33	33
	95	54	151	300

[a] CID = cubic inch displacement

Table 3. Cross Tabulation of Vehicles by Engine Displacement and Emission Control System Type — All Three Cities

	Catalyst(b)				
	Yes		No		
	Secondary Air(c)		Secondary Air		
CID(a)	Yes	No	Yes	No	Total Number of Vehicles
150 or Less	15	15	50	15	95
151 to 259	14	23	7	10	54
260 or More	60	89	2	0	151
	89	127	59	25	300

(a)CID = cubic inch displacement

(b)Oxidation catalyst

(c)Secondary air injection system

Table 4. Cross Tabulation of Vehicles by Inertia Test Weight and Emission Control System Type — All Three Cities

	Catalyst(a)				
	Yes		No		
	Secondary Air(b)		Secondary Air		
Inertia Test Weight Group (lb)	Yes	No	Yes	No	Total Number of Vehicles
2500 or Less	10	3	23	14	50
2501 to 3500	35	44	29	11	119
3501 to 4500	33	58	7	0	98
Greater than 4501	11	22	0	0	33
	89	127	59	25	300

(a)Oxidation catalyst

(b)Secondary air injection system

Table 5. Cross Tabulation of Vehicles by Fuel System and Emission Control System Type — All Three Cities

	Catalyst[a]				
	Yes		No		
	Secondary Air[b]		Secondary Air		
Fuel System Type	Yes	No	Yes	No	Total Number of Vehicles
Fuel Injection	1	3	11	15	30
Carburetion	88	124	48	10	270
	89	127	59	25	300

[a] Oxidation catalyst

[b] Secondary air injection system

Table 6. Cross Tabulation of Vehicles by Inertia Test Weight and Fuel System Type — All Three Cities

Inertia Test Weight Group (lb)	Fuel System Type		Total Number of Vehicles
	Fuel Injection	Carburetion	
0 to 2500	19	31	50
2501 to 3500	7	112	119
3501 to 4500	4	94	98
4501 or Greater	0	33	33
	30	270	300

Table 7. Cross Tabulation of Vehicles by Engine Displacement and Fuel System Type — All Three Cities

CID[a] Group	Fuel System Type		Total Number of Vehicles
	Injection	Carburetion	
150 or Less	24	71	95
151 to 259	6	48	54
260 or More	0	151	151
	30	270	300

[a] CID = cubic inch displacement

Table 8. Cross Tabulation of Vehicles by Engine Displacement and Transmission Type — All Three Cities

CID[a] Group	Transmission Type		Total Number of Vehicles
	Automatic	Manual	
150 or Less	33	62	95
151 to 259	45	9	54
260 or More	151	0	151
	229	71	300

[a] CID = cubic inch displacement

Table 9. Cross Tabulation of Vehicles by Inertia Test Weight and Transmission Type — All Three Cities

Inertia Test Weight Group (lb)	Transmission Type		Total Number of Vehicles
	Automatic	Manual	
0 to 2500	10	40	50
2501 to 3500	88	31	119
3501 to 4500	98	0	98
4501 or Greater	33	0	33
	229	71	300

Table 10. Cross Tabulation of Vehicles by Manufacturer and Engine Displacement — All Three Cities

Manufacturer	Engine Displacement			Total Number of Vehicles
	150 CID[(a)] or Less	151 to 259 CID	260 CID or Greater	
General Motors	12	13	74	99
Ford	6	13	42	61
Chrysler	0	7	29	36
American Motors	0	12	6	18
Datsun	8	1	0	9
Toyota	9	0	0	9
VW, Audi, Porsche	21	1	0	22
Honda	6	0	0	6
Others	33	7	0	40
	95	54	151	300

(a) CID = cubic inch displacement

Table 11. Cross Tabulation of Vehicles by Manufacturer and Engine Displacement — Chicago

Manufacturer	Engine Displacement			Total Number of Vehicles
	150 CID[(a)] or Less	151 to 259 CID	260 CID or Greater	
General Motors	4	5	24	33
Ford	2	4	14	20
Chrysler	0	3	9	12
American Motors	0	4	2	6
Datsun	2	1	0	3
Toyota	3	0	0	3
VW, Audi, Porsche	7	0	0	7
Honda	2	0	0	2
Others	12	2	0	14
	32	19	49	100

(a) CID = cubic inch displacement

Table 12. Cross Tabulation of Vehicles by Manufacturer and Engine Displacement — Houston

Manufacturer	Engine Displacement			Total Number of Vehicles
	150 CID[a] or Less	151 to 259 CID	260 CID or Greater	
General Motors	4	4	25	33
Ford	2	5	14	21
Chrysler	0	2	10	12
American Motors	0	4	2	6
Datsun	3	0	0	3
Toyota	3	0	0	3
VW, Audi, Porsche	8	0	0	8
Honda	2	0	0	2
Others	11	1	0	12
	33	16	51	100

(a) CID = cubic inch displacement

Table 13. Cross Tabulation of Vehicles by Manufacturer and Engine Displacement – Phoenix

Manufacturer	Engine Displacement			Total Number of Vehicles
	150 CID[a] or Less	151 to 259 CID	260 CID or Greater	
General Motors	4	4	25	33
Ford	2	4	14	20
Chrysler	0	2	10	12
American Motors	0	4	2	6
Datsun	3	0	0	3
Toyota	3	0	0	3
VW, Audi, Porsche	6	1	0	7
Honda	2	0	0	2
Others	10	4	0	14
	30	19	51	100

[a] CID = cubic inch displacement

Table 14a. Federal Short Cycle — Means and Standard Deviations by City

City	No. of Vehicles	Emission (gm/mi)					
		HC		CO		NO_x	
		Mean	SD(a)	Mean	SD	Mean	SD
Chicago	100	0.854	0.739	13.16	15.52	1.761	0.831
Houston	100	1.194	1.204	17.84	25.69	1.796	0.882
Phoenix	100	0.934	0.919	14.62	18.21	1.818	0.940

(a) SD = standard deviation

Table 14b. Associated Tests of Significance

Emission	Equality of Means		Homogeneity of Variance	
	F-Value(a)	Level of Significance	Bartlett Test	Level of Significance
HC	3.33	0.04	23.6	0
CO	1.39	0.25	27.1	0
NO_x	0.11	0.90	1.52	0.47
$Log_{10}(HC)$	2.51	0.08	0.48	0.79
$Log_{10}(CO)$	0.10	0.90	0.98	0.62
$Log_{10}(NO_x)$	0.02	0.98	1.59	0.45

(a) Degrees of freedom are 2, 297

Table 15a. Federal Short Cycle — Means and Standard Deviations by Engine Displacement — All Three Cities

CID[a]	No. of Vehicles	Emission (gm/mi)					
		HC		CO		NO_x	
		Mean	SD[b]	Mean	SD	Mean	SD
Less than 150	95	0.978	1.020	11.97	11.80	1.454	0.754
150 to 260	54	0.781	0.665	12.33	18.76	1.845	0.899
Greater than 260	151	1.080	1.041	18.27	24.30	1.985	0.895

[a] CID = cubic inch displacement

[b] SD = standard deviation

Table 15b. Associated Tests of Significance

Emission	Equality of Means		Homogeneity of Variance	
	F-Value[a]	Level of Significance	Bartlett Test	Level of Significance
HC	1.87	0.16	13.9	0
CO	3.53	0.03	51.3	0
NO_x	11.4	0	3.67	0.16
$\text{Log}_{10}(\text{HC})$	1.29	0.28	2.37	0.31
$\text{Log}_{10}(\text{CO})$	1.61	0.20	49.1	0
$\text{Log}_{10}(\text{NO}_x)$	13.1	0	6.37	0.04

[a] Degrees of freedom are 2, 297

Table 16a. Federal Three-Mode — Means and Standard Deviations by City

Test Mode	City	No. of Vehicles	Emission (ppm)					
			HC		CO		NO_x	
			Mean	SD[a]	Mean	SD	Mean	SD
High Speed	Chicago	100	61	72	4439	7907	1131	549
	Houston		40	46	2345	6202	1288	714
	Phoenix		53	34	2864	5571	1540	781
Low Speed	Chicago	100	57	47	4036	7116	649	485
	Houston		45	43	2784	6427	793	587
	Phoenix		59	47	2442	5099	963	697
Idle in Drive	Chicago	78	114	116	16015	22949	160	226
	Houston	75	104	125	16687	21182	149	163
	Phoenix	76	115	91	15324	21155	159	114
Idle in Neutral	Chicago	100	112	121	14049	20671	74	79
	Houston		114	151	14018	18592	68	43
	Phoenix		99	90	12546	19169	73	33

[a] SD = standard deviation

Table 16b. Associated Tests of Significance

Test Mode	Emission	Equality of Means		Homogeneity of Variance	
		F-Value[a]	Level of Significance	Bartlett Test	Level of Significance
High Speed	HC	3.87	0.02	57.7	0
	CO	2.70	0.07	13.1	0
	NO_x	9.00	0	12.5	0
	$Log_{10}(HC)$	12.4	0	3.0	0.22
	$Log_{10}(CO)$	9.81	0	8.11	0.02
	$Log_{10}(NO_x)$	7.56	0	0.06	0.97
Low Speed	HC	2.71	0.07	0.88	0.64
	CO	1.79	0.17	10.9	0
	NO_x	6.99	0	12.7	0
	$Log_{10}(HC)$	6.61	0	2.64	0.27
	$Log_{10}(CO)$	4.21	0.02	10.3	0.01
	$Log_{10}(NO_x)$	6.19	0	0.14	0.93
Idle in Drive	HC	0.23	0.80	7.61	0.02
	CO	0.07	0.93	0.68	0.71
	NO_x	0.09	0.92	33.7	0
	$Log_{10}(HC)$	2.63	0.07	9.77	0.01
	$Log_{10}(CO)$	0.14	0.87	7.33	0.03
	$Log_{10}(NO_x)$	1.72	0.18	9.22	0.01
Idle in Neutral	HC	0.44	0.65	25.3	0
	CO	0.19	0.82	1.29	0.55
	NO_x	0.32	0.73	82.2	0
	$Log_{10}(HC)$	1.07	0.34	14.5	0
	$Log_{10}(CO)$	0.59	0.55	8.62	0.01
	$Log_{10}(NO_x)$	1.85	0.16	22.3	0

[a] Degrees of freedom are 2, 297

Table 17a. Federal Three-Mode — Means and Standard Deviations by Engine Displacement — All Three Cities

Test Mode	CID[a] Group	No. of Vehicles	Emission (ppm)					
			HC		CO		NO_x	
			Mean	SD[b]	Mean	SD	Mean	SD
High Speed	Less than 150	95	58	41	4602	7875	1511	856
	150 to 260	54	47	40	1633	4000	1160	598
	Greater than 260	151	49	64	2911	6480	1257	610
Low Speed	Less than 150	95	60	44	3521	4488	834	562
	150 to 260	54	61	60	2722	7479	813	693
	Greater than 260	151	47	40	2945	6798	778	606
Idle in Drive	Less than 150	33	148	155	19619	24106	125	94
	150 to 260	45	120	104	18828	25125	198	151
	Greater than 260	151	100	100	14625	20117	151	191
Idle in Neutral	Less than 150	95	109	134	12620	18820	68	33
	150 to 260	54	105	106	15180	22000	95	100
	Greater than 260	151	108	122	15530	18950	66	41

[a] CID = cubic inch displacement

[b] SD = standard deviation

Table 17b. Associated Tests of Significance

Test Mode	Emission	Equality of Means		Homogeneity of Variance	
		F-Value[a]	Level of Significance	Bartlett Test	Level of Significance
High Speed	HC	0.94	0.39	28.7	-0-
	CO	3.80	0.02	26.3	-0-
	NO_x	5.64	-0-	16.3	-0-
	$Log_{10}(HC)$	2.58	0.08	1.87	0.40
	$Log_{10}(CO)$	11.9	-0-	2.74	0.26
	$Log_{10}(NO_x)$	2.30	0.10	8.99	0.01
Low Speed	HC	3.20	0.04	15.8	-0-
	CO	0.36	0.70	22.8	-0-
	NO_x	0.26	0.77	3.11	0.21
	$Log_{10}(HC)$	3.28	0.04	1.55	0.46
	$Log_{10}(CO)$	9.66	-0-	5.53	0.06
	$Log_{10}NO_x)$	0.20	0.82	2.14	0.34
Idle in Drive	HC	2.76	0.07	12.6	-0-
	CO	0.95	0.39	4.18	0.13
	NO_x	1.95	0.15	21.0	-0-
	$Log_{10}(HC)$	2.95	0.05	2.19	0.34
	$Log_{10}(CO)$	3.08	0.05	4.76	0.09
	$Log_{10}(NO_x)$	4.58	0.01	0.48	0.79
Idle in Neutral	HC	0.02	0.98	3.68	0.16
	CO	0.30	0.74	2.15	0.34
	NO_x	5.82	-0-	114.0	-0-
	$Log_{10}(HC)$	0.30	0.74	2.35	0.31
	$Log_{10}(CO)$	2.61	0.08	11.8	-0-
	$Log_{10}(NO_x)$	4.68	0.01	0.30	0.86

(a) Degrees of freedom are 2, 297

Table 18a. FTP Means and Standard Deviations by Mileage Group – All Three Cities

Mileage Group(a)	No. of Vehicles	FTP(b) Emission (gm/mi)					
		HC		CO		NO_x	
		Mean	SD(c)	Mean	SD	Mean	SD
4000 Miles or Less	70	1.09	0.657	18.66	14.80	2.11	0.801
Greater than 4000 Miles	230	1.45	1.141	25.71	26.85	2.48	1.005

(a) Number of accumulated miles on vehicles tested

(b) Federal emission certification test procedure

(c) SD = standard deviation

Table 18b. Associated Tests of Significance

Emission	Equality of Means		Homogeneity of Variance	
	F-Value(a)	Level of Significance	Bartlett Test	Level of Significance
HC	6.29	0.01	26.0	-0-
CO	4.42	0.04	29.8	-0-
NO_x	8.08	-0-	4.97	0.03
Log_{10} (HC)	7.59	0.01	0.385	0.54
Log_{10} (CO)	1.89	0.17	5.60	0.02
Log_{10} (NO_x)	7.01	0.01	0.398	0.53

(a) Degrees of freedom are 1, 298

Table 19. Correlation Coefficient Summary by Accumulated Mileage – All Three Cities

Short Test	Mileage Group[a]	Test Mode	No. of Vehicles	ST/FTP[b] Correlation Coefficients[c]					
				HC	CO	NO_x	Log (HC)	Log (CO)	Log (NO_x)
Federal Short Cycle	4000 or less		70	0.91	0.80	0.79	0.85	0.82	0.84
	Greater than 4000		230	0.76	0.90	0.82	0.78	0.82	0.82
Federal Three-Mode	4000 or less	High speed	70	0.13*	0.16*	0.36	0.21	0.17	0.42
		Low speed	70	0.29	0.31	0.40	0.33	0.21	0.47
		Idle in drive	48	0.80	0.61	-0.08*	0.51	0.68	-0.30
		Idle in neutral	70	0.37	0.55	0.02*	0.37	0.54	0.12
	Greater than 4000	High speed	230	0.33	0.37	0.54	0.34	0.24	0.59
		Low speed	230	0.52	0.54	0.49	0.46	0.38	0.57
		Idle in drive	181	0.54	0.67	0.23	0.69	0.75	0.31
		Idle in neutral	230	0.45	0.71	0.14*	0.63	0.70	0.27

[a] Number of accumulated miles on vehicles tested

[b] ST/FTP = short test/federal emission certification test procedure

[c] Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

Table 20a. FTP Means and Standard Deviations — by City

City	No. of Vehicles	FTP[a] Emission (gm/mi)					
		HC		CO		NO_x	
		Mean	SD[b]	Mean	SD	Mean	SD
Chicago	100	1.283	0.834	21.665	17.145	2.375	0.896
Houston	100	1.534	1.335	27.598	32.812	2.446	1.050
Phoenix	100	1.288	0.930	22.934	21.378	2.357	0.974

[a] FTP = federal emission certification test procedure

[b] SD = standard deviation

Table 20b. Associated Tests of Significance

Emission	Equality of Means		Homogeneity of Variance	
	F-Value[a]	Level of Significance	Bartlett Test	Approximate Level of Significance
HC	1.841	0.160	25.162	0.0
CO	1.602	0.203	44.224	0.0
NO_x	0.234	0.792	2.506	0.287
$\log_{10}$ (HC)	0.941	0.392	5.423	0.067
$\log_{10}$ (CO)	0.185	0.831	12.967	0.002
$\log_{10}$ (NO_x)	0.135	0.874	2.333	0.313

[a] Degrees of freedom are 2, 297

Table 21. Correlation Coefficient Summary – All Three Cities

Short Test	Test Mode	No. of Vehicles	ST/FTP(a) Correlation Coefficients(b)					
			HC	CO	NO_x	Log (HC)	Log (CO)	Log (NO_x)
Federal Short Cycle		300	0.78	0.89	0.81	0.80	0.82	0.82
Federal Three-Mode	High speed	300	0.31	0.33	0.52	0.31	0.22	0.56
	Low speed	300	0.47	0.46	0.48	0.43	0.35	0.55
	Idle in neutral	300	0.45	0.69	0.11*	0.58	0.67	0.23
	Idle in drive	229	0.58	0.67	0.12*	0.66	0.74	0.27

(a) ST/FTP = short test/federal emission certification test procedure

(b) Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

Table 22. Correlation Coefficient Summary – Chicago

Short Test	Test Mode	No. of Vehicles	ST/FTP(a) Correlation Coefficients(b)					
			HC	CO	NO_x	Log (HC)	Log (CO)	Log (NO_x)
Federal Short Cycle		100	0.88	0.82	0.81	0.81	0.80	0.85
Federal Three-Mode	High speed	100	0.12*	0.31	0.43	0.33	0.34	0.51
	Low speed	100	0.38	0.52	0.40	0.45	0.39	0.47
	Idle in neutral	100	0.42	0.52	0.03*	0.50	0.57	0.27
	Idle in drive	78	0.52	0.50	0.01*	0.54	0.63	0.22*

(a) ST/FTP = short test/federal emission certification test procedure

(b) Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

Table 23. Correlation Coefficient Summary – Houston

Short Test	Test Mode	No. of Vehicles	ST/FTP(a) Correlation Coefficient(b)					
			HC	CO	NO_x	Log (HC)	Log (CO)	Log (NO_x)
Federal Short Cycle		100	0.91	0.97	0.78	0.88	0.87	0.81
Federal Three-Mode	High speed	100	0.66	0.45	0.44	0.42	0.19*	0.52
	Low speed	100	0.76	0.53	0.41	0.58	0.33	0.56
	Idle in neutral	100	0.47	0.79	0.34	0.67	0.68	0.32
	Idle in drive	75	0.60	0.76	0.36	0.76	0.79	0.46

(a)ST/FTP = short test/federal emission certification test procedure

(b)Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

Table 24. Correlation Coefficient Summary – Phoenix

Short Test	Test Mode	No. of Vehicles	ST/FTP(a) Correlation Coefficient(b)					
			HC	CO	NO_x	Log (HC)	Log (CO)	Log (NO_x)
Federal Short Cycle		100	0.45	0.76	0.85	0.73	0.79	0.82
Federal Three-Mode	High speed	100	0.25	0.32	0.73	0.27	0.20	0.73
	Low speed	100	0.28	0.41	0.66	0.34	0.36	0.66
	Idle in neutral	100	0.44	0.80	0.03*	0.61	0.74	0.08*
	Idle in drive	76	0.71	0.81	-0.05*	0.75	0.78	0.03*

(a)ST/FTP = short test/federal emission certification test procedure

(b)Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

Table 25a. FTP Means and Standard Deviations by Engine Displacement — All Three Cities

CID(a) Group	No. of Vehicles	FTP(b) Emission (gm/mi)					
		HC		CO		NO_x	
		Mean	SD(c)	Mean	SD	Mean	SD
150 and Less	95	1.327	0.712	16.789	11.065	2.095	0.939
151 to 259	54	1.271	1.021	21.718	19.348	2.428	0.838
260 and Greater	151	1.429	1.241	29.484	30.744	2.568	0.999

(a) CID = cubic inch displacement

(b) FTP = federal emission certification test procedure

(c) SD = standard deviation

Table 25b. Associated Tests of Significance

Emission	Equality of Means		Homogeneity of Variance	
	F-Value(a)	Level of Significance	Bartlett Test	Approximate Level of Significance
HC	0.547	0.579	31.651	0.0
CO	8.373	0.0	97.662	0.0
NO_x	7.235	0.001	2.336	0.313
Log_{10} (HC)	0.319	0.727	3.277	0.196
Log_{10} (CO)	2.832	0.061	25.554	0.0
Log_{10} (NO_x)	10.133	0.0	10.476	0.006

(a) Degrees of freedom are 2, 297

Table 26. Correlation Coefficient Summary by Engine Displacement – All Three Cities

Short Test	CID[a] Group	Test Mode	No. of Vehicles	ST/FTP[b] Correlation Coefficients[c]					
				HC	CO	NO_x	Log(HC)	Log(CO)	Log(NO_x)
Federal Short Cycle	150 or Less		95	0.71	0.63	0.82	0.81	0.76	0.83
	151 to 259		54	0.53	0.90	0.83	0.74	0.84	0.84
	260 or More		151	0.89	0.92	0.79	0.82	0.86	0.78
Federal Three-Mode	150 or Less	High speed	95	0.25	0.40	0.61	0.35	0.19*	0.68
		Low speed	95	0.41	0.36	0.63	0.45	0.35	0.71
		Idle in neutral	95	0.45	0.63	0.06*	0.48	0.55	0.20
		Idle in drive	33	0.75	0.43	0.30*	0.57	0.54	0.41
	151 to 259	High speed	54	0.25*	0.34	0.59	0.23*	-0.03*	0.45
		Low speed	54	0.36	0.72	0.74	0.41	0.27	0.71
		Idle in neutral	54	0.38	0.65	0.04*	0.49	0.58	0.22*
		Idle in drive	45	0.78	0.66	0.13*	0.73	0.75	0.28*
	260 or More	High speed	151	0.34	0.43	0.58	0.30	0.37	0.60
		Low speed	151	0.62	0.47	0.36	0.44	0.46	0.42
		Idle in neutral	151	0.49	0.82	0.24	0.65	0.79	0.30
		Idle in drive	151	0.60	0.80	0.10*	0.69	0.80	0.23

[a] CID = cubic inch displacement

[b] ST/FTP = short test/federal emission certification test procedure

[c] Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

Table 27a. FTP Means and Standard Deviations by Inertia Test Weight -- All Three Cities

Inertia Test Weight Group (lb)	No. of Vehicles	FTP(a) Emission (gm/mi)					
		HC		CO		NO_x	
		Mean	SD(b)	Mean	SD	Mean	SD
2500 and Less	50	1.382	1.020	15.071	10.563	1.868	0.763
2501 to 3500	119	1.291	0.921	20.909	22.370	2.486	1.043
3501 to 4500	98	1.309	1.191	25.859	24.066	2.557	0.944
Greater than 4500	33	1.799	1.107	43.753	37.019	2.365	0.829

(a) FTP = federal emission certification test procedure

(b) SD = standard deviation

Table 27b. Associated Tests of Significance

Emission	Equality of Means		Homogeneity of Variance	
	F-Value(a)	Level of Significance	Bartlett Test	Approximate Level of Significance
HC	2.162	0.093	7.324	0.064
CO	10.996	0.0	58.248	0.0
NO_x	6.498	0.0	7.384	0.062
$Log_{10}(HC)$	3.101	0.027	0.413	0.938
$Log_{10}(CO)$	8.225	0.0	8.787	0.033
$Log_{10}(NO_x)$	8.305	0.0	7.120	0.070

(a) Degrees of freedom are 3, 296

Table 28. Correlation Coefficient Summary by Inertia Test Weight Group — All Three Cities

Short Test	Inertia Test Weight Group (lb)	Test Mode	No. of Vehicles	ST/FTP(a) Correlation Coefficients(b)					
				HC	CO	NO_x	Log(HC)	Log(CO)	Log(NO_x)
Federal Short Cycle	0 to 2500		50	0.49	0.73	0.76	0.74	0.71	0.78
	2501 to 3500		119	0.76	0.86	0.81	0.83	0.82	0.84
	3501 to 4500		98	0.92	0.91	0.81	0.87	0.88	0.80
	4501 or More		33	0.73	0.88	0.77	0.63	0.81	0.81
Federal Three-Mode	0 to 2500	High speed	50	0.20*	0.53	0.54	0.39	0.46	0.64
		Low speed	50	0.33	0.42	0.50	0.49	0.36	0.68
		Idle in neutral	50	0.32	0.56	0.08*	0.51	0.47	0.18*
		Idle in drive	10	0.37*	0.05*	0.33*	0.58*	-0.13*	0.40*
	2501 to 3500	High speed	119	0.41	0.50	0.62	0.30	0.20	0.61
		Low speed	119	0.55	0.61	0.64	0.46	0.45	0.66
		Idle in neutral	119	0.49	0.59	0.09*	0.57	0.70	0.31
		Idle in drive	88	0.66	0.58	0.18*	0.72	0.81	0.31
	3501 to 4500	High speed	98	0.36	0.28	0.54	0.33	0.32	0.57
		Low speed	98	0.51	0.45	0.33	0.41	0.40	0.44
		Idle in neutral	98	0.42	0.86	0.20	0.58	0.80	0.24
		Idle in drive	98	0.53	0.86	0.05*	0.63	0.80	0.14*
	4501 or More	High speed	33	0.28*	0.29*	0.53	0.34*	0.26*	0.60
		Low speed	33	0.48	0.35	0.30*	0.47	0.39	0.43
		Idle in neutral	33	0.56	0.75	0.30*	0.64	0.62	0.36
		Idle in drive	33	0.64	0.76	0.10*	0.71	0.72	0.31*

(a) ST/FTP = short test/federal emission certification test procedure

(b) Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

Table 29a. FTP Means and Standard Deviations by Emission Control System Type — All Three Cities

Catalyst	Secondary Air Injection	No. of Vehicles	FTP[a] Emission (gm/mi)					
			HC		CO		NO_x	
			Mean	SD[b]	Mean	SD	Mean	SD
Yes	Yes	89	1.118	1.144	17.493	18.083	2.670	1.150
Yes	No	127	1.498	1.078	34.025	31.538	2.283	0.832
No	Yes	59	1.284	0.641	15.213	7.607	2.246	0.998
No	No	25	1.799	1.241	17.767	11.844	2.312	0.700

(a)FTP = federal emission certification test procedure

(b)SD = standard deviation

Table 29b. Associated Tests of Significance

Emission	Equality of Means		Homogeneity of Variance	
	F-Value[a]	Level of Significance	Bartlett Test	Approximate Level of Significance
HC	3.905	0.009	23.895	0.0
CO	13.533	0.0	130.884	0.0
NO_x	3.539	0.015	15.311	0.002
$\log_{10}(HC)$	7.873	0.0	7.838	0.051
$\log_{10}(CO)$	11.755	0.0	27.375	0.0
$\log_{10}(NO_x)$	2.252	0.082	13.093	0.005

(a)Degrees of freedom are 3, 296

Table 30. Correlation Coefficient Summary by Emission Control System Type – All Three Cities

Short Test	Catalyst/Air[a]	Test Mode	No. of Vehicles	ST/FTP[b] Correlation Coefficients[c]					
				HC	CO	NO_x	Log(HC)	Log(CO)	Log(NO_x)
Federal Short Cycle	Yes/Yes		89	0.94	0.86	0.83	0.85	0.83	0.83
	Yes/No		127	0.84	0.92	0.77	0.82	0.87	0.76
	No/Yes		59	0.74	0.54	0.86	0.78	0.75	0.90
	No/No		25	0.32*	0.36	0.90	0.54	0.76	0.89
Federal Three-Mode	Yes/Yes	High speed	89	0.73	0.39	0.65	0.38	0.62	0.70
		Low speed	89	0.59	0.54	0.60	0.42	0.66	0.59
		Idle in neutral	89	0.25	0.80	0.05*	0.35	0.76	0.13*
		Idle in drive	76	0.46	0.77	-0.05*	0.40	0.82	0.15*
	Yes/No	High speed	127	0.13*	0.35	0.48	0.23	0.22	0.51
		Low speed	127	0.50	0.51	0.47	0.46	0.41	0.55
		Idle in neutral	127	0.56	0.65	0.12*	0.71	0.68	0.22
		Idle in drive	117	0.62	0.67	0.22	0.75	0.72	0.26
	No/Yes	High speed	59	0.34	0.40	0.65	0.41	0.41	0.70
		Low speed	59	0.36	0.52	0.74	0.42	0.39	0.77
		Idle in neutral	59	0.40	0.50	0.29	0.41	0.40	0.50
		Idle in drive	24	0.85	0.40*	0.55	0.58	0.58	0.62
	No/No	High speed	25	-0.01*	0.39*	0.28*	0.15*	0.32*	0.08*
		Low speed	25	0.16*	-0.02*	0.47	0.36*	0.12*	0.41
		Idle in neutral	25	0.31*	0.69	0.40	0.42	0.76	0.46
		Idle in drive	12	0.86	0.88	0.51*	0.77	0.70	0.51*

[a] Secondary air injection system

[b] ST/FTP = short test/federal emission certification test procedure

[c] Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

Table 31a. FTP Means and Standard Deviations by Fuel System Type - All Three Cities

Fuel System Type	No. of Vehicles	FTP[(a)] Emission (gm/mi)					
		HC		CO		NO_x	
		Mean	SD[(b)]	Mean	SD	Mean	SD
Fuel Injection	30	1.598	1.224	17.158	12.181	2.036	0.647
Carburetion	270	1.344	1.038	24.833	25.650	2.433	0.995

(a) FTP = federal emission certification test procedure

(b) SD = standard deviation

Table 31b. Associated Tests of Significance

Emission	Equality of Means		Homogeneity of Variance	
	F-Value[(a)]	Level of Significance	Bartlett Test	Approximate Level of Significance
HC	1.452	0.229	1.550	0.216
CO	2.614	0.107	19.842	0.0
NO_x	4.534	0.034	7.740	0.006
$\log_{10}$ (HC)	2.336	0.128	0.043	0.837
$\log_{10}$ (CO)	1.706	0.193	1.469	0.228
$\log_{10}$ (NO_x)	2.892	0.090	3.600	0.059

(a) Degrees of freedom are 1, 298

Table 32. Correlation Coefficient Summary by Fuel System Type – All Three Cities

Short Test	Fuel System Type	Test Mode	No. of Vehicles	ST/FTP[a] Correlation Coefficients[b]					
				HC	CO	NO_x	Log (HC)	Log (CO)	Log (NO_x)
Federal Short Cycle	Fuel Injection		30	0.45	0.79	0.62	0.78	0.90	0.57
	Carburetion		270	0.82	0.89	0.82	0.81	0.82	0.84
Federal Three-Mode	Fuel Injection	High speed	30	0.11*	0.47	0.63	0.35*	0.52	0.59
		Low speed	30	0.22*	0.11*	0.33*	0.38	0.45	0.42
		Idle in neutral	30	0.36	0.61	-0.20*	0.51	0.75	-0.19*
		Idle in drive	11	0.80	0.54*	-0.07*	0.64	0.58*	-0.01*
	Carburetion	High speed	270	0.32	0.34	0.53	0.29	0.23	0.57
		Low speed	270	0.50	0.49	0.49	0.43	0.37	0.57
		Idle in neutral	270	0.46	0.70	0.13	0.58	0.68	0.27
		Idle in drive	218	0.58	0.69	0.11*	0.66	0.76	0.27

[a] ST/FTP = short test/federal emission certification test procedure

[b] Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

Table 33a. FTP Means and Standard Deviations by Transmission Type - All Three Cities

Transmission Type	No. of Vehicles	FTP(a) Emission (gm/mi)					
		HC		CO		NO_x	
		Mean	SD(b)	Mean	SD	Mean	SD
Automatic	229	1.345	1.086	26.301	26.979	2.513	0.983
Manual	71	1.442	0.967	16.854	13.142	2.005	0.834

(a)FTP = federal emission certification test procedure

(b)SD = standard deviation

Table 33b. Associated Tests of Significance

Emission	Equality of Means		Homogeneity of Variance	
	F-Value(a)	Level of Significance	Bartlett Test	Approximate Level of Significance
HC	0.045	0.502	1.399	0.238
CO	8.096	0.005	41.861	-0-
NO_x	15.558	-0-	2.729	0.099
Log_{10} (HC)	2.052	0.153	0.758	0.385
Log_{10} (CO)	4.379	0.037	11.922	0.001
Log_{10} (NO_x)	17.961	-0-	0.992	0.321

(a)Degrees of freedom are 1, 298

Table 34. Correlation Coefficient Summary by Transmission Type – All Three Cities

Short Test	Transmission Type	Test Mode	No. of Vehicles	ST/FTP[a] Correlation Coefficients[b] HC	CO	NO_x	Log (HC)	Log (CO)	Log (NO_x)
Federal Short Cycle	Automatic		229	0.87	0.91	0.80	0.83	0.85	0.81
	Manual		71	0.42	0.66	0.82	0.72	0.75	0.82
Federal Three-Mode	Automatic	High speed	229	0.31	0.33	0.57	0.29	0.27	0.57
		Low speed	229	0.48	0.48	0.49	0.41	0.39	0.55
		Idle in neutral	229	0.49	0.71	0.11*	0.60	0.70	0.23
		Idle in drive	229	0.58	0.67	0.12*	0.66	0.74	0.27
	Manual	High speed	71	0.28	0.50	0.65	0.33	0.14*	0.72
		Low speed	71	0.42	0.56	0.56	0.47	0.40	0.71
		Idle in neutral	71	0.33	0.67	0.09*	0.48	0.60	0.33
		Idle in drive	--	--	--	--	--	--	--

[a] ST/FTP = short test/federal emission certification test procedure

[b] Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

Table 35a. FTP Means and Standard Deviations by Manufacturer – All Three Cities

Manufacturer	No. of Vehicles	FTP[(a)] Emission (gm/mi)					
		HC		CO		NO_x	
		Mean	SD[(b)]	Mean	SD	Mean	SD
General Motors	99	1.378	1.180	26.165	24.772	2.400	0.956
Ford	61	1.245	1.003	22.550	26.106	2.742	1.045
Chrysler	36	1.726	1.248	45.648	36.359	2.352	0.811
American Motors	18	1.052	0.583	13.076	9.466	2.764	0.696
Others	86	1.361	0.911	15.990	10.254	2.076	0.957

(a) FTP = federal emission certification test procedure

(b) SD = standard deviation

Table 35b. Associated Tests of Significance

Emission	Equality of Means		Homogeneity of Variance	
	F-Value[(a)]	Level of Significance	Bartlett Test	Approximate Level of Significance
HC	1.649	0.162	16.848	0.002
CO	11.747	0.0	108.921	0.0
NO_x	5.204	0.001	5.456	0.249
Log_{10} (HC)	2.238	0.065	3.529	0.479
Log_{10} (CO)	8.926	0.0	21.243	0.0
Log_{10} (NO_x)	7.087	0.0	19.122	0.001

(a) Degrees of freedom are 4, 295

Table 36. Correlation Coefficient Summary by Manufacturer – All Three Cities

Short Test	Manufacturer	Test Mode	No. of Vehicles	ST/FTP[a] Correlation Coefficients[b] HC	CO	NO$_x$	Log (HC)	Log (CO)	Log (NO$_x$)
Federal Short Cycle	General Motors		99	0.90	0.90	0.92	0.88	0.88	0.91
	Ford		61	0.94	0.96	0.78	0.87	0.85	0.77
	Chrysler		36	0.81	0.94	0.77	0.72	0.90	0.69
	American Motors		18	0.94	0.91	0.93	0.97	0.90	0.95
	Others		86	0.51	0.65	0.85	0.77	0.76	0.84
Federal Three-Mode	General Motors	High speed	99	0.35	0.29	0.42	0.34	0.30	0.50
		Low speed	99	0.61	0.65	0.55	0.53	0.55	0.60
		Idle in neutral	99	0.50	0.70	0.17*	0.73	0.75	0.33
		Idle in drive	92	0.55	0.73	0.28	0.77	0.81	0.32
	Ford	High speed	61	0.33	0.43	0.65	0.26	0.38	0.66
		Low speed	61	0.40	0.53	0.67	0.35	0.51	0.58
		Idle in neutral	61	0.42	0.85	-0.10*	0.50	0.69	-0.01*
		Idle in drive	55	0.63	0.84	-0.25*	0.55	0.73	-0.09*
	Chrysler	High speed	36	0.48	0.57	0.65	0.30*	0.21*	0.53
		Low speed	36	0.60	0.64	0.58	0.39	0.27*	0.64
		Idle in neutral	36	0.54	0.65	0.09*	0.44	0.57	0.26*
		Idle in drive	36	0.56	0.68	-0.12*	0.42	0.63	0.12*
	American Motors	High speed	18	0.23*	0.68	0.72	0.23*	0.80	0.51
		Low speed	18	0.58	0.60	0.39*	0.59	0.78	0.38*
		Idle in neutral	18	0.56	0.84	0.24*	0.76	0.91	0.26*
		Idle in drive	16	0.81	0.84	0.29*	0.90	0.85	0.37*
	Others	High speed	86	0.21*	0.47	0.64	0.34	0.47	0.69
		Low speed	86	0.31	0.49	0.69	0.42	0.46	0.73
		Idle in neutral	86	0.33	0.53	0.11*	0.41	0.50	0.25
		Idle in drive	30	0.82	0.32*	0.60	0.58	0.48	0.58

(a)ST/FTP = short test/federal emission certification test procedure

(b)Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

Table 37. Correlation Coefficient Summary for 150 CID[a] and Less by Manufacturer — All Three Cities

Short Test	Manufacturer	Test Mode	No. of Vehicles	ST/FTP[b] Correlation Coefficients[c]					
				HC	CO	NO_x	Log (HC)	Log (CO)	Log (NO_x)
Federal Short Cycle	General Motors		12	0.84	0.89	0.94	0.87	0.89	0.93
	Ford		6	0.95	0.83	0.35*	0.94	0.95	0.46
	Datsun		8	0.95	0.93	0.89	0.98	0.92	0.87
	Toyota		9	0.88	0.50*	0.82	0.84	0.52*	0.80
	VW, Audi, Porsche		21	0.88	0.71	0.49	0.81	0.68	0.67
	Honda		6	0.20*	-0.21*	0.74*	0.15*	-0.18*	0.66*
	Others		33	0.74	0.48	0.91	0.80	0.85	0.94
Federal Three-Mode	General Motors	High speed	12	0.25*	0.15*	0.84	0.46*	0.05*	0.81
		Low speed	12	0.61	0.70	0.32*	0.68	0.67	0.54*
		Idle in drive	6	0.88	0.96	0.04*	0.92	0.93	0.02*
		Idle in neutral	12	0.30*	0.66	0.19*	0.67	0.80	0.14*
	Ford	High speed	6	-0.17*	0.55*	0.17*	-0.10*	0.79*	0.26*
		Low speed	6	-0.22*	0.76*	0.61*	-0.16*	0.91	0.55*
		Idle in drive	3	-0.81*	0.93*	0.74*	0.89*	1.0*	0.55*
		Idle in neutral	6	0.86	0.07*	0.31*	0.60*	0.56*	0.04*
	Datsun	High speed	8	0.53*	0.93	-0.49*	0.76	0.91	-0.50*
		Low speed	8	0.61*	0.93	0.72	0.77	0.95	0.68
		Idle in drive	2	---	---	---	---	---	---
		Idle in neutral	8	0.40*	0.42*	-0.07*	0.70*	0.74	0.05*
	Toyota	High speed	9	0.69	-0.07*	0.56*	0.53*	-0.13*	0.50*
		Low speed	9	0.87	-0.17*	0.81	0.84	-0.25*	0.79
		Idle in drive	2	---	---	---	---	---	---
		Idle in neutral	9	0.66*	0.42*	0.00*	0.28*	0.33*	-0.02*
	VW, Audi, Porsche	High speed	21	0.20*	0.59	0.77	0.41*	0.53	0.78
		Low speed	21	0.53	0.43*	0.66	0.60	0.42*	0.78
		Idle in drive	5	0.77*	0.10*	0.77*	0.71*	-0.23*	0.67*
		Idle in neutral	21	0.60	0.53	0.24*	0.64	0.33*	0.31*
	Honda	High speed	6	0.89	0.29*	0.66*	0.82	0.30*	0.56*
		Low speed	6	0.23*	-0.26*	0.24*	0.18*	-0.22*	0.18*
		Idle in drive	0	---	---	---	---	---	---
		Idle in neutral	6	0.94	0.35*	0.62*	0.90	0.43*	-0.17*
	Other	High speed	33	0.15*	0.47	0.61	0.20*	0.53	0.60
		Low speed	33	0.24*	0.31*	0.68	0.27*	0.49	0.71
		Idle in drive	15	0.84	0.44*	0.55	0.51*	0.71	0.44*
		Idle in neutral	33	0.37	0.41	0.37	0.36	0.59	0.33*

[a] CID = cubic inch displacement

[b] ST/FTP = short test/federal emission certification test procedure

[c] Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

Table 38. Correlation Coefficient Summary for 151 to 259 CID(a) by Manufacturer — All Three Cities

Short Test	Manufacturer	Test Mode	No. of Vehicles	ST/FTP(b) Correlation Coefficients(c)					
				HC	CO	NO_x	Log (HC)	Log (CO)	Log (NO_x)
Federal Short Cycle	General Motors		13	0.93	0.98	0.90	0.90	0.94	0.94
	Ford		13	0.92	0.93	0.44*	0.84	0.89	0.57
	Chrysler		7	0.80	0.94	0.95	0.71	0.73	0.92
	American Motors		12	0.88	0.89	0.92	0.90	0.84	0.95
	Other(d)		9	0.18*	0.90	0.90	0.67	0.91	0.87
Federal Three-Mode	General Motors	High speed	13	0.13*	-0.40*	0.05*	-0.01*	-0.48*	0.03*
		Low speed	13	0.50*	0.87	0.81	0.57	0.38*	0.77
		Idle in drive	12	0.79	0.60	-0.12*	0.84	0.80	0.22*
		Idle in neutral	13	0.82	0.58	-0.09*	0.68	0.41*	0.23*
	Ford	High speed	13	0.79	0.91	0.67	0.37*	0.36*	0.67
		Low speed	13	0.79	0.91	0.70	0.46*	0.41*	0.71*
		Idle in drive	10	0.21*	0.55*	-0.08*	0.31*	0.73	-0.09*
		Idle in neutral	13	0.73	0.88	-0.35*	0.42*	0.61	-0.32*
	Chrysler	High speed	7	0.70*	0.09*	0.74*	0.54*	0.18*	0.54*
		Low speed	7	0.71*	0.18*	0.94	0.53*	0.25*	0.90*
		Idle in drive	7	0.89	0.89	0.09*	0.85	0.49*	0.25*
		Idle in neutral	7	0.87	0.85	0.18*	0.78	0.44*	0.38*
	American Motors	High speed	12	0.03*	0.60	0.69	0.13*	0.38*	0.43*
		Low speed	12	0.35*	0.15*	0.49*	0.40*	0.10*	0.56*
		Idle in drive	10	0.65	0.86	0.32*	0.61*	0.67	0.46*
		Idle in neutral	12	0.27*	0.89	0.26*	0.29*	0.81*	0.29*
	Other(d)	High speed	9	0.13*	0.08*	0.72	0.26*	0.50*	0.58*
		Low speed	9	0.07*	0.86	0.78	0.24*	0.85	0.54*
		Idle in drive	6	0.68*	0.93	0.85	0.46*	0.93	0.72*
		Idle in neutral	9	0.02*	0.92	0.78	0.17*	0.89	0.68

(a) CID = cubic inch displacement

(b) ST/FTP = short test/federal emission certification test procedure

(c) Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

(d) "Other" category includes one Datsun and one Porsche

Table 39. Correlation Coefficient Summary for 260 CID[(a)] and Greater by Manufacturer – All Three Cities

Short Test	Manu-facturer	Test Mode	No. of Vehicles	ST/FTP[(b)] Correlation Coefficients[(c)]					
				HC	CO	NO_x	Log (HC)	Log (CO)	Log (NO_x)
Federal Short Cycle	General Motors		74	0.91	0.88	0.92	0.90	0.87	0.90
	Ford		42	0.95	0.97	0.88	0.88	0.82	0.87
	Chrysler		29	0.80	0.94	0.78	0.71	0.91	0.73
	American Motors		6	0.86	0.54*	0.95	0.89	0.38*	0.96
Federal Three-Mode	General Motors	High speed	74	0.37	0.40	0.56	0.37	0.42	0.59
		Low speed	74	0.71	0.63	0.68	0.52	0.57	0.70
		Idle in drive	74	0.59	0.79	0.37	0.80	0.83	0.40
		Idle in neutral	74	0.51	0.84	0.42	0.75	0.80	0.43
	Ford	High speed	42	0.20*	0.38	0.65	0.17*	0.38	0.66
		Low speed	42	0.40	0.67	0.73	0.35	0.60	0.64
		Idle in drive	42	0.64	0.84	-0.19*	0.59	0.74	0.03*
		Idle in neutral	42	0.37	0.85	0.01*	0.50	0.76	0.11*
	Chrysler	High speed	29	0.46	0.55	0.62	0.26*	0.11*	0.53
		Low speed	29	0.58	0.64	0.52	0.34*	0.20*	0.64
		Idle in drive	29	0.59	0.74	-0.16*	0.40	0.72	0.05*
		Idle in neutral	29	0.54	0.72	0.06*	0.41	0.67	0.20*
	American Motors	High speed	6	0.11*	0.30*	0.93	0.07*	0.60*	0.96
		Low speed	6	-0.02*	0.43*	0.33*	-0.10*	0.69*	0.33*
		Idle in drive	6	0.36*	0.36*	0.82	0.33*	0.68*	0.73*
		Idle in neutral	6	0.42*	0.36*	0.66*	0.41*	0.68*	0.62*

(a) CID = cubic inch displacement

(b) ST/FTP = short test/federal emission certification test procedure

(c) Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

Table 40a. FTP Means and Standard Deviations by Engine Displacement – Chicago

CID(a)	No. of Vehicles	FTP(b) Emissions (gm/mi)					
		HC		CO		NO_x	
		Mean	SD(c)	Mean	SD	Mean	SD
150 and Less	32	1.346	0.469	17.089	7.928	2.241	0.883
151 to 259	19	1.071	0.421	19.333	12.558	2.294	0.698
260 and Greater	49	1.324	1.098	25.557	21.794	2.494	0.969

(a)CID = cubic inch displacement

(b)FTP = federal emission certification test procedure

(c)SD = standard deviation

Table 40b. Associated Tests of Significance

Emission	Equality of Means		Homogeneity of Variance	
	F-Value(a)	Level of Significance	Bartlett Test	Approximate Level of Significance
HC	0.764	0.469	34.475	0.0
CO	2.664	0.075	32.790	0.0
NO_x	0.868	0.423	2.537	0.287
Log_{10} (HC)	1.745	0.180	13.481	0.001
Log_{10} (CO)	0.692	0.503	10.203	0.007
Log_{10} (NO_x)	0.845	0.433	1.867	0.399

(a)Degrees of freedom are 2, 97

Table 41. Correlation Coefficient Summary by Engine Displacement – Chicago

Short Test	CID[a] Group	Test Mode	No. of Vehicles	ST/FTP[b] Correlation Coefficients[c]					
				HC	CO	NO_x	Log (HC)	Log (CO)	Log (NO_x)
Federal Short Cycle	150 or less		32	0.84	0.77	0.90	0.75	0.73	0.92
	151 to 259		19	0.82	0.86	0.79	0.81	0.90	0.81
	260 or more		49	0.91	0.84	0.76	0.84	0.83	0.81
Federal Three-Mode	150 or less	High speed	32	0.43	0.51	0.41	0.40	0.24*	0.49
		Low speed	32	0.59	0.44	0.45	0.59	0.17*	0.56
		Idle in neutral	32	0.31*	0.58	0.12*	0.45	0.51	0.29*
		Idle in drive	11	0.55*	0.52*	-0.03*	0.44*	0.27*	-0.04*
	151 to 259	High speed	19	0.25*	0.32*	0.31*	0.22*	0.31*	0.38*
		Low speed	19	0.36*	0.67	0.66	0.19*	0.43*	0.65
		Idle in neutral	19	0.64	0.74	0.02*	0.55	0.62	0.11*
		Idle in drive	18	0.71	0.71	0.20*	0.64	0.70	0.28*
	260 or more	High speed	49	0.06*	0.35	0.57	0.32	0.44	0.62
		Low speed	49	0.43	0.52	0.33	0.46	0.52	0.39
		Idle in neutral	49	0.55	0.76	0.09*	0.50	0.69	0.35
		Idle in drive	49	0.61	0.80	-0.01*	0.55	0.73	0.29

[a] CID = cubic inch displacement

[b] ST/FTP = short test/federal emission certification test procedure

[c] Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

Table 42a. FTP Means and Standard Deviations by Inertia Test Weight — Chicago

Inertia Test Weight Group (lb)	No. of Vehicles	FTP[a] Emission (gm/mi)					
		HC		CO		NO_x	
		Mean	SD[b]	Mean	SD	Mean	SD
2500 and Less	15	1.35	0.463	15.1	7.11	2.11	0.786
2501 to 3500	43	1.11	0.527	17.4	12.3	2.44	0.914
3501 to 4500	30	1.49	1.270	27.9	27.9	2.46	0.943
Greater than 4500	12	1.31	0.653	29.4	20.2	2.26	0.865

[a] FTP = federal emission certification test procedure

[b] SD = standard deviation

Table 42b. Associated Tests of Significance

Emission	Equality of Means		Homogeneity of Variance	
	F-Value[a]	Level of Significance	Bartlett Test	Approximate Level of Significance
HC	1.33	0.269	35.1	0.0
CO	4.13	0.008	25.2	0.0
NO_x	0.67	0.572	0.657	0.887
$Log_{10}(HC)$	1.11	0.349	5.56	0.142
$Log_{10}(CO)$	4.55	0.005	3.30	0.358
$Log_{10}(NO_x)$	0.69	0.558	0.346	0.953

[a] Degrees of freedom are 3, 96

Table 43. Correlation Coefficient Summary by Inertia Test Weight Group – Chicago

Short Test	Inertia Test Weight Group (lb)	Test Mode	No. of Vehicles	ST/FTP[a] Correlation Coefficient[b]					
				HC	CO	NO_x	Log(HC)	Log(CO)	Log(NO_x)
Federal Short Cycle	0 to 2500		15	0.80	0.64	0.91	0.70	0.71	0.94
	2501 to 3500		43	0.87	0.83	0.78	0.83	0.84	0.84
	3501 to 4500		30	0.93	0.88	0.77	0.88	0.81	0.77
	4501 and more		12	0.77	0.67	0.90	0.67	0.78	0.95
Federal Three-Mode	0 to 2500	High speed	15	0.27*	0.17*	0.26*	0.13*	0.08*	0.37*
		Low speed	15	0.51	0.32*	0.40*	0.48*	0.03*	0.53
		Idle in neutral	15	0.14*	0.45*	-0.01*	0.22*	0.39*	0.22*
		Idle in drive	4	-0.77*	0.28*	-0.46*	-0.69*	-0.09*	-0.38*
	2501 to 3500	High speed	43	0.46	0.34	0.50	0.41	0.41	0.56
		Low speed	43	0.52	0.55	0.40	0.44	0.48	0.49
		Idle in neutral	43	0.61	0.63	0.05*	0.66	0.77	0.26*
		Idle in drive	32	0.79	0.66	0.33*	0.75	0.83	0.33*
	3501 to 4500	High speed	30	0.01*	0.28*	0.61	0.26*	0.20*	0.61
		Low speed	30	0.38	0.66	0.40	0.46*	0.38	0.46
		Idle in neutral	30	0.54	0.82	-0.17*	0.46	0.66	0.01*
		Idle in drive	30	0.59	0.83	-0.22	0.49	0.65	-0.07*
	4501 and more	High speed	12	0.62	0.47*	0.58	0.67	0.55*	0.65
		Low speed	12	0.54*	0.42*	0.50*	0.56*	0.58	0.49*
		Idle in neutral	12	0.19*	0.50*	0.60	0.33*	0.53*	0.79
		Idle in drive	12	0.43*	0.64	0.56*	0.54*	0.65	0.76

[a] ST/FTP = short test/federal emission certification test procedure

[b] Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

Table 44a. FTP Means and Standard Deviations by Emission Control System Type — Chicago

Catalyst	Secondary Air Injection	No. of Vehicles	FTP[a] Emission (gm/mi)					
			HC		CO		NO_x	
			Mean	SD[b]	Mean	SD	Mean	SD
Yes	Yes	30	1.139	1.005	19.995	16.407	2.612	1.074
Yes	No	44	1.293	0.875	25.528	20.473	2.229	0.778
No	Yes	17	1.364	0.475	14.749	7.024	2.450	0.964
No	No	9	1.563	0.455	21.408	10.773	2.158	0.489

(a) FTP = federal emission certification test procedure

(b) SD = standard deviation

Table 44b. Associated Tests of Significance

Emission	Equality of Means		Homogeneity of Variance	
	F-Value[a]	Level of Significance	Bartlett Test	Approximate Level of Significance
HC	0.686	0.563	13.783	0.004
CO	1.805	0.151	20.971	0.0
NO_x	1.320	0.272	7.994	0.051
Log_{10} (HC)	2.404	0.072	8.931	0.034
Log_{10} (CO)	1.639	0.185	4.109	0.261
Log_{10} (NO_x)	0.775	0.511	3.943	0.279

(a) Degrees of freedom are 3, 96

Table 45. Correlation Coefficient Summary by Emission Control System Type – Chicago

Short Test	Catalyst/Air[a]	Test Mode	No. of Vehicles	ST/FTP[b] Correlation Coefficients[c]					
				HC	CO	NO_x	Log(HC)	Log(CO)	Log(NO_x)
Federal Short Cycle	Yes/Yes		30	0.91	0.76	0.80	0.85	0.81	0.83
	Yes/No		44	0.86	0.85	0.77	0.82	0.86	0.86
	No/Yes		17	0.91	0.92	0.94	0.77	0.94	0.93
	No/No		9	0.81	0.82	0.70	0.86	0.84	0.74
Federal Three-Mode	Yes/Yes	High speed	30	0.30*	0.49*	0.60	0.36	0.70	0.64
		Low speed	30	0.14*	0.51	0.69	0.34*	0.61	0.61
		Idle in neutral	30	0.23*	0.64	-0.05*	0.24*	0.80	0.16*
		Idle in drive	27	0.47	0.58	-0.11*	0.21*	0.87	-0.04*
	Yes/No	High speed	44	0.03*	0.32	0.44	0.20*	0.31	0.50
		Low speed	44	0.52	0.56	0.36	0.41	0.47	0.48
		Idle in neutral	44	0.46	0.48	0.10*	0.55	0.51	0.38
		Idle in drive	42	0.59	0.60	0.20*	0.66	0.56	0.42
	No/Yes	High speed	17	0.52	0.48*	0.56	0.43	0.32*	0.70
		Low speed	17	0.68	0.72	0.69	0.65	0.44*	0.73
		Idle in neutral	17	0.75	0.54	0.18*	0.65	0.53	0.43*
		Idle in drive	5	0.88	0.38*	0.25*	0.84*	-0.13*	0.50*
	No/No	High speed	9	-0.10*	0.36*	0.04*	-0.03*	0.23*	0.01*
		Low speed	9	0.36*	-0.07*	0.68	0.47*	-0.05*	0.60*
		Idle in neutral	9	0.75	0.85	-0.04*	0.79	0.90	0.14*
		Idle in drive	4	0.88*	0.82*	-0.74*	0.75*	0.96	-0.68*

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[a] Secondary air injection system

[b] ST/FTP = short test/federal emission certification test procedure

[c] Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

Table 56a. FTP Means and Standard Deviations by Fuel System Type — Chicago

Fuel Injection	No. of Vehicles	FTP[a] Emission (gm/mi)					
		HC		CO		NO_x	
		Mean	SD[b]	Mean	SD	Mean	SD
Yes	10	1.588	0.448	15.506	7.991	2.378	0.600
No	90	1.249	0.862	22.349	17.770	2.375	0.925

[a] FTP = federal emission certification test procedure

[b] SD = standard deviation

Table 46b. Associated Tests of Significance

Emission	Equality of Means		Homogeneity of Variance	
	F-Value[a]	Level of Significance	Bartlett Test	Approximate Level of Significance
HC	1.492	0.225	4.967	0.029
CO	1.440	0.233	6.930	0.010
NO_x	0.0	0.991	2.433	0.126
Log_{10} (HC)	4.340	0.040	6.518	0.012
Log_{10} (CO)	0.900	0.345	1.627	0.211
Log_{10} (NO_x)	0.163	0.687	3.785	0.056

[a] Degrees of freedom are 1, 98

Table 47. Correlation Coefficient Summary by Fuel System Type – Chicago

Short Test	Fuel Injection	Test Mode	No. of Vehicles	ST/FTP[a] Correlation Coefficients[b]					
				HC	CO	NO_x	Log(HC)	Log(CO)	Log(NO_x)
Federal Short Cycle	Yes		10	0.79	0.82	0.75	0.81	0.81	0.67
	No		90	0.88	0.82	0.81	0.80	0.81	0.86
Federal Three-Mode	Yes	High speed	10	-0.07*	0.01*	0.52*	0.08*	-0.05*	0.36*
		Low speed	10	0.03*	0.31*	0.15*	0.17*	0.20*	0.10*
		Idle in neutral	10	0.91	0.83	-0.64	0.86	0.76	-0.73
		Idle in drive	4	0.95*	0.90*	-0.99	0.81*	0.64*	-0.96
	No	High speed	90	0.11*	0.32	0.44	0.30	0.38	0.52
		Los speed	90	0.39	0.53	0.40	0.43	0.43	0.49
		Idle in neutral	90	0.40	0.54	0.05*	0.48	0.59	0.29
		Idle in drive	74	0.51	0.53	0.02*	0.52	0.67	0.23

[a] ST/FTP = short test/federal emission certification test procedure

[b] Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

Table 48a. FTP Means and Standard Deviations by Transmission Type — Chicago

Transmission Type	No. of Vehicles	FTP[a] Emission (gm/mi)					
		HC		CO		NO_x	
		Mean	SD[b]	Mean	SD	Mean	SD
Automatic	78	1.280	0.919	23.547	18.689	2.408	0.920
Manual	22	1.294	0.430	14.992	6.732	2.258	0.812

[a] FTP = federal emission certification test procedure

[b] SD = standard deviation

Table 48b. Associated Tests of Significance

Emission	Equality of Means		Homogeneity of Variance	
	F-Value[a]	Level of Significance	Bartlett Test	Approximate Level of Significance
HC	0.005	0.946	13.933	0.0
CO	4.420	0.038	22.660	0.0
NO_x	0.481	0.490	0.486	0.489
$\log_{10}$ (HC)	1.197	0.277	8.333	0.004
$\log_{10}$ (CO)	2.561	0.113	7.601	0.006
$\log_{10}$ (NO_x)	0.474	0.493	0.158	0.693

[a] Degrees of freedom are 1, 98

Table 49. Correlation Coefficient Summary by Transmission Type — Chicago

Short Test	Transmission Type	Test Mode	No. of Vehicles	ST/FTP[a] Correlation Coefficients[b]					
				HC	CO	NO_x	Log(HC)	Log(CO)	Log(NO_x)
Federal Short Cycle	Automatic		78	0.89	0.82	0.80	0.83	0.82	0.84
	Manual		22	0.82	0.84	0.89	0.70	0.85	0.90
Federal Three-Mode	Automatic	High speed	78	0.09*	0.30	0.47	0.31	0.37	0.49
		Low speed	78	0.35	0.53	0.38	0.41	0.46	0.42
		Idle in neutral	78	0.50	0.55	0.01*	0.48	0.61	0.18*
		Idle in drive	78	0.52	0.50	0.01*	0.54	0.63	0.22*
	Manual	High speed	22	0.57	0.61	0.57	0.43	0.39*	0.75
		Low speed	22	0.73	0.69	0.54	0.74	0.34*	0.74
		Idle in neutral	22	0.31	0.48	0.18*	0.56	0.54	0.59
		Idle in drive	--	----	----	----	----	----	----

[a] ST/FTP = short test/federal emission certification test procedure

[b] Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

Table 50a. FTP Means and Standard Deviations by Manufacturer — Chicago

Manufacturer	No. of Vehicles	FTP[a] Emission (gm/mi)					
		HC		CO		NO_x	
		Mean	SD[b]	Mean	SD	Mean	SD
General Motors	33	1.319	0.980	26.071	22.743	2.249	0.967
Ford	20	1.230	1.148	19.618	12.710	2.707	0.958
Chrysler	12	1.091	0.621	25.013	19.604	2.243	0.631
American Motors	6	1.053	0.524	19.017	13.519	2.497	0.592
Others	29	1.406	0.472	17.224	10.115	2.319	0.902

[a] FTP = federal emission certification test procedure

[b] SD = standard deviation

Table 50b. Associated Tests of Significance

Emission	Equality of Means		Homogeneity of Variance	
	F-Value[a]	Level of Significance	Bartlett Test	Approximate Level of Significance
HC	0.455	0.768	22.706	0.0
CO	1.266	0.289	21.250	0.0
NO_x	0.973	0.426	4.059	0.416
$\log_{10}$ (HC)	1.377	0.248	10.189	0.043
$\log_{10}$ (CO)	0.488	0.744	9.744	0.051
$\log_{10}(NO_x)$	1.125	0.349	5.762	0.233

[a] Degrees of freedom are 4, 95

Table 51. Correlation Coefficient Summary by Manufacturer – Chicago

Short Test	Manu-facturer	Test Mode	No. of Vehicles	ST/FTP[a] Correlation Coefficients[b]					
				HC	CO	NO_x	Log (HC)	Log (CO)	Log (NO_x)
Federal Short Cycle	General Motors		33	0.91	0.88	0.95	0.89	0.88	0.95
	Ford		20	0.96	0.75	0.84	0.87	0.82	0.86
	Chrysler		12	0.74	0.88	0.43*	0.66	0.83	0.41*
	American Motors		6	0.94	0.93	0.96	0.97	0.97	0.96
	Others		29	0.80	0.86	0.89	0.78	0.85	0.91
Federal Three-Mode	General Motors	High speed	33	0.04*	0.34*	0.51	0.30*	0.48	0.53
		Low speed	33	0.58	0.60	0.50	0.52	0.62	0.57
		Idle in neutral	33	0.51	0.57	0.13*	0.65	0.69	0.43
		Idle in drive	31	0.61	0.71	0.37	0.73	0.77	0.53
	Ford	High speed	20	0.38*	0.52	0.64	0.35*	0.45	0.69
		Low speed	20	0.02*	0.80	0.75	-0.10*	0.60	0.65
		Idle in neutral	20	0.38*	0.70	-0.38*	0.43*	0.62	-0.42*
		Idle in drive	19	0.61	0.84	-0.15*	0.55	0.77	-0.17*
	Chrysler	High speed	12	-0.29*	0.35*	0.23*	0.16*	0.36*	0.41*
		Low speed	12	-0.37*	-0.10*	0.54*	0.10*	0.04*	0.61
		Idle in neutral	12	0.33*	0.39*	-0.31*	-0.04*	0.34*	-0.26*
		Idle in drive	12	0.30*	0.47*	-0.43*	-0.04*	0.33*	-0.39*
	American Motors	High speed	6	0.50*	0.64*	0.96	0.54*	0.68*	0.95
		Low speed	6	0.54*	0.63*	0.06*	0.51*	0.71*	-0.16*
		Idle in neutral	6	0.90	0.89	-0.38*	0.90	0.88	-0.37*
		Idle in drive	6	0.92	0.84	0.26*	0.92	0.74*	0.23*
	Others	High speed	29	0.34*	0.19*	0.42	0.32*	0.19*	0.51
		Low speed	29	0.57	0.[illegible]	0.61	0.58	0.43	0.65
		Idle in neutral	29	0.40	0.5[illegible]	0.12*	0.47	0.59	0.31*
		Idle in drive	10	0.70	0.33*	0.08*	0.43*	0.21*	0.09*

(a) ST/FTP = short test/federal emission certification test procedure

(b) Correlation coefficients are statistically significant at the 95 percent program confidence level except where indicated by an asterisk

Table 52a. FTP Means and Standard Deviations by Engine Displacement — Houston

CID(a)	No. of Vehicles	FTP(b) Emission (gm/mi)					
		HC		CO		NO_x	
		Mean	SD(c)	Mean	SD	Mean	SD
150 and Less	33	1.518	0.903	18.930	13.750	2.044	0.941
151 to 259	16	1.227	0.842	22.014	26.480	2.469	0.754
260 and Greater	51	1.640	1.659	34.959	41.052	2.700	1.129

(a) CID = cubic inch displacement

(b) FTP = federal emission certification test procedure

(c) SD = standard deviation

Table 52b. Associated Tests of Significance

Emission	Equality of Means		Homogeneity of Variance	
	F-Value(a)	Level of Significance	Bartlett Test	Approximate Level of Significance
HC	0.580	0.562	17.919	0.0
CO	2.761	0.068	36.282	0.0
NO_x	4.154	0.019	3.762	0.158
Log_{10} (HC)	0.549	0.579	1.577	0.461
Log_{10} (CO)	0.264	0.768	13.801	0.001
Log_{10} (NO_x)	5.380	0.006	5.741	0.060

(a) Degrees of freedom are 2, 97

Table 53. Correlation Coefficient Summary by Engine Displacement – Houston

Short Test	CID[a] Group	Test Mode	No. of Vehicles	ST/FTP[b] Correlation Coefficients[c]					
				HC	CO	NO_x	Log (HC)	Log (CO)	Log (NO_x)
Federal Short Cycle	150 or less		33	0.90	0.82	0.78	0.86	0.77	0.88
	151 to 259		16	0.94	0.96	0.56	0.83	0.78	0.65
	260 or more		51	0.94	0.98	0.79	0.90	0.92	0.73
Federal Three-Mode	150 or less	High speed	33	0.29*	0.33*	0.61	0.46	0.03*	0.76
		Low speed	33	0.53	0.38	0.66	0.56	0.37	0.79
		Idle in neutral	33	0.61	0.79	0.42	0.63	0.40	0.45
		Idle in drive	11	0.92	0.45*	0.85	0.76	0.48*	0.85
	151 to 259	High speed	16	-0.14*	-0.31*	0.32*	-0.11*	-0.61	0.19*
		Low speed	16	0.86	0.95	0.56	0.66	0.11*	0.65
		Idle in neutral	16	0.82	0.68	0.34*	0.58	0.33	0.47*
		Idle in drive	13	0.90	0.75	0.57	0.79	0.66	0.64
	260 or more	High speed	51	0.75	0.65	0.54	0.46	0.48	0.59
		Low speed	51	0.83	0.59	0.31	0.58	0.48	0.39
		Idle in neutral	51	0.40	0.84	0.35	0.70	0.86	0.34
		Idle in drive	51	0.57	0.76	0.31	0.77	0.85	0.34

[a] CID = cubic inch displacement

[b] ST/FTP = short test/federal emission certification test procedure

[c] Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

Table 54a. FTP Means and Standard Deviations by Inertia Test Weight — Houston

Inertia Test Weight Group (lb)	No. of Vehicles	FTP[a] Emission (gm/mi)					
		HC		CO		NO_x	
		Mean	SD[b]	Mean	SD	Mean	SD
2500 and less	19	1.437	0.777	17.143	12.383	1.818	0.785
2501 to 3500	38	1.531	1.330	25.795	32.411	2.477	1.149
3501 to 4500	33	1.385	1.523	26.318	29.035	2.822	1.010
Greater than 4500	10	2.219	1.500	58.541	53.905	2.286	0.680

[a] FTP = federal emission certification test procedure

[b] SD = standard deviation

Table 54b. Associated Tests of Significance

Emission	Equality of Means		Homogeneity of Variance	
	F-Value[a]	Level of Significance	Bartlett Test	Approximate Level of Significance
HC	1.051	0.374	9.076	0.031
CO	3.995	0.010	26.544	0.0
NO_x	4.120	0.009	5.481	0.148
Log_{10} (HC)	1.582	0.199	2.303	0.522
Log_{10} (CO)	1.849	0.143	8.080	0.048
Log_{10} (NO_x)	5.490	0.002	7.163	0.072

[a] Degrees of freedom are 3, 96

Table 55. Correlation Coefficient Summary by Inertia Test Weight Group — Houston

Short Test	Inertia Test Weight Group (lb)	Test Mode	No. of Vehicles	ST/FTP(a) Correlation Coefficients(b)					
				HC	CO	NO_x	Log (HC)	Log (CO)	Log (NO_x)
Federal Short Cycle	0 to 2500		19	0.94	0.87	0.89	0.82	0.70	0.92
	2501 to 3500		38	0.88	0.95	0.73	0.89	0.85	0.72
	3501 to 4500		33	0.94	0.98	0.81	0.88	0.90	0.80
	4501 or more		10	0.93	0.98	0.53*	0.90	0.96	0.57*
Federal Three-Mode	0 to 2500	High speed	19	0.47	0.58	0.65	0.57	0.45*	0.84
		Low speed	19	0.81	0.57	0.44*	0.72	0.33*	0.79
		Idle in neutral	19	0.82	0.67	0.54	0.76	0.26*	0.52
		Idle in drive	3	1.00	-0.90*	0.99*	1.00	-0.91*	1.00
	2501 to 3500	High speed	38	0.66	0.70	0.57	0.32*	0.04*	0.47
		Low speed	38	0.75	0.64	0.68	0.56	0.45	0.69
		Idle in neutral	38	0.52	0.68	0.31*	0.60	0.63	0.50
		Idle in drive	29	0.70	0.62	0.33*	0.77	0.82	0.56
	3501 to 4500	High speed	33	0.87	0.42	0.45	0.52	0.35	0.54
		Low speed	33	0.85	0.44	0.12*	0.57	0.35	0.31*
		Idle in neutral	33	0.25*	0.93	0.41	0.65	0.82	0.39
		Idle in drive	33	0.43	0.91	0.37	0.76	0.81	0.35
	4501 or more	High speed	10	0.49*	0.69	0.21*	0.42*	0.49*	0.45*
		Low speed	10	0.66	0.55*	0.14*	0.61*	0.41*	0.32*
		Idle in neutral	10	0.62*	0.85	0.33*	0.79	0.90	0.19*
		Idle in drive	10	0.75	0.85	0.27*	0.82	0.91	0.12*

(a) ST/FTP = short test/federal emission certification test procedure

(b) Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

Table 56a. FTP Means and Standard Deviations by Emission Control System Type — Houston

Catalyst	Secondary Air Injection	No. of Vehicles	FTP[a] Emission (gm/mi)					
			HC		CO		NO_x	
			Mean	SD[b]	Mean	SD	Mean	SD
Yes	Yes	27	1.185	1.589	14.424	13.494	2.882	1.391
Yes	No	41	1.800	1.416	45.798	43.568	2.344	0.810
No	Yes	22	1.383	0.869	14.674	7.680	2.140	1.000
No	No	10	1.713	0.922	16.983	13.409	2.368	0.661

[a] FTP = federal emission certification test procedure

[b] SD = standard deviation

Table 56b. Associated Tests of Significance

Emission	Equality of Means		Homogeneity of Variance	
	F-Value[a]	Level of Significance	Bartlett Test	Approximate Level of Significance
HC	1.328	0.270	9.951	0.021
CO	8.839	0.0	80.159	0.0
NO_x	2.423	0.071	12.471	0.007
$\log_{10}$ (HC)	2.558	0.060	3.406	0.344
$\log_{10}$ (CO)	6.820	0.0	17.147	0.001
$\log_{10}$ (NO_x)	1.354	0.262	11.711	0.010

[a] Degrees of Freedom are 3, 96

Table 57. Correlation Coefficient Summary by Emission Control System Type – Houston

Short Test	Catalyst/Air[(a)]	Test Mode	No. of Vehicles	ST/FTP[(b)] Correlation Coefficients[(c)] HC	CO	NO_x	Log (HC)	Log (CO)	Log (NO_x)
Federal Short Cycle	Yes/Yes		27	0.97	0.90	0.84	0.80	0.87	0.89
	Yes/No		41	0.91	0.98	0.70	0.93	0.90	0.66
	No/Yes		22	0.94	0.87	0.75	0.83	0.90	0.84
	No/No		10	0.98	0.91	0.94	0.98	0.72	0.91
Federal Three-Mode	Yes/Yes	High speed	27	0.94	0.41	0.78	0.48	0.52	0.81
		Low speed	27	0.94	0.57	0.64	0.55	0.56	0.67
		Idle in neutral	27	0.14*	0.79	0.09*	0.35*	0.62	0.10*
		Idle in drive	24	0.40*	0.82	0.17*	0.48	0.76	0.48
	Yes/No	High speed	41	0.56	0.64	0.27*	0.46	0.49	0.35
		Low speed	41	0.76	0.63	0.36	0.64	0.55	0.55
		Idle in neutral	41	0.59	0.75	0.52	0.79	0.76	0.37
		Idle in drive	38	0.68	0.69	0.54	0.83	0.81	0.44
	No/Yes	High speed	22	0.33*	0.56	0.61	0.52	0.50	0.66
		Low speed	22	0.32*	0.64	0.74	0.52	0.43	0.80
		Idle in neutral	22	0.40*	0.64	0.62	0.50	0.51	0.75
		Idle in drive	9	0.92	0.76	0.84	0.78	0.78	0.76
	No/No	High speed	10	0.55*	0.93	-0.09*	0.49*	0.68	-0.19*
		Low speed	10	0.86	-0.01*	0.11*	0.74	0.25*	-0.02*
		Idle in neutral	10	0.80	0.90	0.62*	0.69	0.75	0.53*
		Idle in drive	4	0.70*	0.56*	0.43*	0.63*	0.41*	0.27*

[(a)] Secondary air injection system

[(b)] ST/FTP = short test/federal emission certification test procedure

[(c)] Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

Table 58a. FTP Means and Standard Deviations by Fuel System Type — Houston

Fuel System Type	No. of Vehicles	FTP(a) Emissions (gm/mi)					
		HC		CO		NO_x	
		Mean	SD(b)	Mean	SD	Mean	SD
Fuel injection	10	1.652	0.937	20.900	14.022	2.032	0.489
Carburetion	90	1.520	1.375	28.343	34.236	2.493	1.09

(a)FTP = federal emissions certification test procedure

(b)SD = standard deviation

Table 58b. Associated Tests of Significance

Emission	Equality of Means		Homogeneity of Variance	
	F-Value(a)	Level of Significance	Bartlett Test	Approximate Level of Significance
HC	0.087	0.769	1.961	0.169
CO	0.461	0.499	8.275	0.005
NO_x	1.744	0.190	6.916	0.010
$\log_{10}$ (HC)	0.840	0.362	0.800	0.380
$\log_{10}$ (CO)	0.026	0.872	2.568	0.116
$\log_{10}$ (NO_x)	0.727	0.369	4.641	0.034

(a)Degrees of freedom are 1, 98

Table 59. Correlation Coefficient Summary by Fuel System Type — Houston

Short Test	Fuel System Type	Test Mode	No. of Vehicles	ST/FTP[a] Correlation Coefficients[b]					
				HC	CO	NO_x	Log (HC)	Log (CO)	Log (NO_x)
Federal Short Cycle	Fuel injection		10	0.97	0.76	0.53*	0.95	0.92	0.40*
	Carburetion		90	0.91	0.97	0.78	0.88	0.87	0.82
Federal Three-Mode	Fuel injection	High speed	10	0.51*	0.77	0.48*	0.64	0.77	0.35*
		Low speed	10	0.82	0.0*	-0.08*	0.72	0.32*	0.02*
		Idle in neutral	10	0.86	0.77	0.14*	0.83	0.82	0.08*
		Idle in drive	3	0.99*	0.47*	0.57*	1.00*	0.58*	0.48*
	Carburetion	High speed	90	0.67	0.45	0.46	0.39	0.19*	0.54
		Low speed	90	0.77	0.61	0.44	0.57	0.36	0.61
		Idle in neutral	90	0.45	0.81	0.35	0.65	0.68	0.34
		Idle in drive	72	0.60	0.76	0.36	0.76	0.80	0.46

[a] ST/FTP = short test/federal emission certification test procedure

[b] Correlation Coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

Table 60a. FTP Means and Standard Deviations by Transmission Type — Houston

Transmission Type	No. of Vehicles	FTP[a] Emission (gm/mi)					
		HC		CO		NO_x	
		Mean	SD[b]	Mean	SD	Mean	SD
Automatic	75	1.514	1.477	30.718	36.511	2.607	1.094
Manual	25	1.591	0.786	18.239	14.461	1.965	0.735

[a] FTP = federal emission certification test procedure

[b] SD = standard deviation

Table 60b. Associated Tests of Significance

Emission	Equality of Means		Homogeneity of Variance	
	F-Value[a]	Level of Significance	Bartlett Test	Approximate Level of Significance
HC	0.061	0.805	11.357	0.001
CO	2.760	0.100	21.790	0.0
NO_x	7.457	0.008	4.934	0.028
Log_{10} (HC)	1.872	0.174	3.070	0.082
Log_{10} (CO)	0.547	0.461	7.249	0.008
Log_{10} (NO_x)	6.764	0.011	0.143	0.707

[a] Degrees of freedom are 1, 98

Table 61. Correlation Coefficient Summary by Transmission Type — Houston

Short Test	Transmission Type	Test Mode	No. of Vehicles	ST/FTP[a] Correlation Coefficients[b]					
				HC	CO	NO_x	Log (HC)	Log (CO)	Log (NO_x)
Federal Short Cycle	Automatic		75	0.91	0.97	0.78	0.89	0.89	0.80
	Manual		25	0.93	0.91	0.72	0.86	0.72	0.82
Federal Three-Mode	Automatic	High speed	75	0.69	0.47	0.55	0.39	0.31	0.60
		Low speed	75	0.79	0.60	0.45	0.55	0.40	0.62
		Idle in neutral	75	0.44	0.84	0.34	0.67	0.75	0.31
		Idle in drive	75	0.60	0.76	0.36	0.76	0.79	0.46
	Manual	High speed	25	0.40	0.24*	0.49	0.51	-0.17*	0.52
		Low speed	25	0.72	0.31*	0.46	0.68	0.34*	0.63
		Idle in neutral	25	0.73	0.80	0.48	0.65	0.55	0.58
		Idle in drive	--	--	--	--	--	--	--

[a] ST/FTP = short test/federal emission certification procedure

[b] Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

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Table 62a. FTP Means and Standard Deviations by Manufacturer — Houston

Manu-facturer	No. of Vehicles	FTP[(a)] Emission (gm/mi)					
		HC		CO		NO_x	
		Mean	SD[(b)]	Mean	SD	Mean	SD
General Motors	33	1.581	1.616	26.897	29.390	2.530	0.980
Ford	21	1.227	1.037	23.531	34.954	3.004	1.278
Chrysler	12	2.325	1.790	70.437	46.412	2.136	0.583
American Motors	6	1.142	0.737	10.377	5.661	2.852	0.613
Others	28	1.453	0.916	16.806	10.936	1.976	0.964

(a) FTP = federal emission certification test procedure

(b) SD = standard deviation

Table 62b. Associated Tests of Significance

Emission	Equality of Means		Homogeneity of Variance	
	F-Value[(a)]	Level of Significance	Bartlett Test	Approximate Level of Significance
HC	1.529	0.200	15.656	0.004
CO	8.228	0.0	49.453	0.0
NO_x	3.809	0.007	9.348	0.060
Log_{10} (HC)	1.767	0.142	3.128	0.553
Log_{10} (CO)	5.984	0.0	13.365	0.012
Log_{10} (NO_x)	4.330	0.003	10.286	0.041

(a) Degrees of freedom are 4, 95

Table 63. Correlation Coefficient Summary by Manufacturer — Houston

Short Test	Manufacturer	Test Mode	No. of Vehicles	ST/FTP[a] Correlation Coefficients[b] HC	CO	NO_x	Log (HC)	Log (CO)	Log (NO_x)
Federal Short Cycle	General Motors		33	0.94	0.97	0.90	0.92	0.90	0.86
	Ford		21	0.93	0.98	0.66	0.88	0.92	0.62
	Chrysler		12	0.92	0.98	0.57*	0.95	0.95	0.59
	American Motors		6	0.98	0.90	0.97	0.97	0.96	0.96
	Others		28	0.91	0.79	0.90	0.84	0.73	0.91
Federal Three-Mode	General Motors	High speed	33	0.85	0.52	0.20*	0.52	0.30*	0.31*
		Low speed	33	0.88	0.81	0.51	0.69	0.55	0.58
		Idle in neutral	33	0.42	0.78	0.50	0.75	0.79	0.52
		Idle in drive	30	0.48	0.73	0.51	0.81	0.84	0.56
	Ford	High speed	21	0.02*	0.70	0.66	0.02*	0.20	0.68
		Low speed	21	0.72	0.88	0.69	0.43*	0.34	0.57
		Idle in neutral	21	0.39*	0.85	0.12*	0.50	0.62	0.19*
		Idle in drive	19	0.68	0.85	-0.08*	0.56	0.67	0.13*
	Chrysler	High speed	12	0.66	0.73	0.34*	0.64	0.39*	0.34*
		Low speed	12	0.79	0.75	0.53*	0.70	0.61	0.75
		Idle in neutral	12	0.62	0.78	0.58	0.79	0.73	0.58
		Idle in drive	12	0.69	0.78	0.59	0.75	0.86	0.55*
	American Motors	High speed	6	-0.68*	0.82	0.55*	-0.70*	0.94	0.27*
		Low speed	6	0.77*	0.79*	0.06*	0.61*	0.94	0.27*
		Idle in neutral	6	0.82	0.77*	0.18*	0.87	0.93	0.23*
		Idle in drive	5	0.86*	0.69*	0.41*	0.89	0.91	0.48*
	Others	High speed	28	0.33*	0.58	0.71	0.50	0.48	0.81
		Low speed	28	0.54	0.32*	0.73	0.58	0.37*	0.80
		Idle in neutral	28	0.59	0.60	0.48	0.58	0.21*	0.52
		Idle in drive	9	0.92	0.09*	0.92	0.77	0.16*	0.90

[a] ST/FTP = short test/federal emission certification test procedure

[b] Correlation Coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

Table 64a. FTP Means and Standard Deviations by Engine Displacement - Phoenix

CID[a] Group	No. of Vehicles	FTP[b] Emission (gm/mi) HC Mean	HC SD[c]	CO Mean	CO SD	NO_x Mean	NO_x SD
150 and Less	30	1.095	0.641	14.112	10.407	1.995	1.005
151 to 259	19	1.509	1.482	23.853	18.668	2.527	1.037
260 and Greater	51	1.319	0.802	27.782	25.410	2.508	0.889

[a] CID = cubic inch displacement

[b] FTP = federal emission test certification procedure

[c] SD = standard deviation

Table 64b. Associated Tests of Significance

Emission	Equality of Means: F-Value[a]	Equality of Means: Level of Significance	Homogeneity of Variance: Bartlett Test	Homogeneity of Variance: Approximate Level of Significance
HC	1.213	0.302	19.320	0.0
CO	4.128	0.019	23.415	0.0
NO_x	3.106	0.049	0.897	0.643
Log_{10} (HC)	1.098	0.338	0.522	0.773
Log_{10} (CO)	3.552	0.033	3.645	0.167
Log_{10} (NO_x)	5.030	0.008	5.804	0.058

[a] Degrees of freedom are 2, 97.

Table 65. Correlation Coefficient Summary by Engine Displacement – Phoenix

Short Test	CID[a] Group	Test Mode	No. of Vehicles	ST/FTP[b] Correlation Coefficients[c]					
				HC	CO	NO_x	Log (HC)	Log (CO)	Log (NO_x)
Federal Short Cycle	150 or less		30	0.42	0.36	0.80	0.83	0.75	0.72
	151 to 259		19	0.33*	0.93	0.95	0.67	0.88	0.95
	260 or more		51	0.70	0.82	0.83	0.70	0.84	0.80
Federal Three-Mode	150 or less	High speed	30	0.23*	0.52	0.85	0.29*	0.34*	0.87
		Low speed	30	0.29*	0.18*	0.82	0.33*	0.40	0.87
		Idle in neutral	30	0.34*	0.74	-0.18*	0.38	0.67	-0.06*
		Idle in drive	11	0.65	0.46*	-0.21*	0.56*	0.83	0.11*
	151 to 259	High speed	19	0.36*	0.60	0.81	0.44*	0.21*	0.77
		Low speed	19	0.27*	0.62	0.87	0.43*	0.30*	0.80
		Idle in neutral	19	0.13*	0.76	0.14*	0.41*	0.82	0.22*
		Idle in drive	14	0.80	0.86	-0.14*	0.76	0.91	-0.04*
	260 or more	High speed	51	0.16*	0.31	0.75	0.15*	0.27*	0.68
		Low speed	51	0.28	0.43	0.49	0.28	0.46	0.51
		Idle in neutral	51	0.71	0.87	0.22*	0.80	0.77	0.21*
		Idle in drive	51	0.76	0.87	-0.02*	0.83	0.80	-0.01*

[a] CID = cubic inch displacement

[b] ST/FTP = short test/federal emission certification test procedure

[c] Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

Table 66a. FTP Means and Standard Deviations by Inertia Test Weight - Phoenix

Inertia Test Weight Group (lb)	No. of Vehicles	FTP(a) Emission (gm/mi)					
		HC		CO		NO_x	
		Mean	SD(b)	Mean	SD	Mean	SD
2500 or less	16	1.344	1.571	12.578	11.013	1.701	0.704
2501 to 3500	38	1.262	0.723	19.983	18.245	2.544	1.094
3501 to 4500	35	1.081	0.631	23.642	20.792	2.392	0.847
Greater than 4500	11	1.957	0.964	45.946	29.192	2.557	0.947

(a)FTP = federal emission certification test procedure

(b)SD = standard deviation

Table 66b. Associated Tests of Significance

Emission	Equality of Means		Homogeneity of Variance	
	F-Value(a)	Level of Significance	Bartlett Test	Approximate Level of Significance
HC	2.629	0.055	24.023	0.0
CO	6.759	0.0	11.845	0.009
NO_x	3.274	0.024	4.677	0.206
Log_{10} (HC)	3.039	0.033	5.758	0.131
Log_{10} (CO)	5.976	0.001	0.679	0.882
Log_{10} (NO_x)	3.779	0.013	4.388	0.232

(a)Degrees of freedom are 3, 96

Table 67. Correlation Coefficient Summary by Inertia Test Weight Group – Phoenix

Short Test	Inertia Test Weight Group (lb)	Test Mode	No. of Vehicles	ST/FTP[a] Correlation Coefficients[b] HC	CO	NO_x	Log (HC)	Log (CO)	Log (NO_x)
Federal Short Cycle	0 to 2500		16	0.21*	0.57	0.44*	0.72	0.74	0.48*
	2501 to 3500		38	0.52	0.71	0.91	0.82	0.81	0.94
	3501 to 4500		35	0.86	0.83	0.86	0.84	0.87	0.83
	4501 or more		11	0.28*	0.68	0.80	0.22*	0.70	0.74
Federal Three-Mode	0 to 2500	High speed	16	0.15*	0.68	0.85	0.43*	0.66	0.84
		Low speed	16	0.13*	0.17*	0.89	0.41*	0.49*	0.90
		Idle in neutral	16	0.15*	0.80	0.02*	0.50	0.72	0*
		Idle in drive	3	0.99*	0.55*	0.80*	1.00[c]	0.67*	0.83*
	2501 to 3500	High speed	38	0.56	0.56	0.80	0.37	0.33	0.82
		Low speed	38	0.64	0.70	0.79	0.47	0.49	0.83
		Idle in neutral	38	0.49	0.80	0.03*	0.50	0.75	0.14*
		Idle in drive	27	0.71	0.82	-0.25*	0.66	0.84	-0.08*
	3501 to 4500	High speed	35	0.29*	0.41	0.72	0.20*	0.32*	0.69
		Low speed	35	0.29*	0.43	0.53	0.25*	0.43	0.54
		Idle in neutral	35	0.82	0.82	0.35	0.79	0.86	0.33*
		Idle in drive	35	0.82	0.84	0.20*	0.83	0.88	0.17*
	4501 or more	High speed	11	-0.03*	0.01*	0.76	-0.03*	-0.0*	0.66
		Low speed	11	0.08*	0.09*	0.36*	-0.16*	0.25*	0.47*
		Idle in neutral	11	0.38*	0.76	0.04*	0.51*	0.42*	0.18*
		Idle in drive	11	0.52*	0.81	-0.24*	0.68	0.62	-0.10*

[a] ST/FTP = short test/federal emission certification test procedure

[b] Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

[c] Only two data points used

Table 68a. FTP Means and Standard Deviations by Emission Control System – Phoenix

Catalyst	Secondary Air Injection	No. of Vehicles	FTP[a] Emission (gm/mi) HC Mean	HC SD[b]	CO Mean	CO SD	NO Mean	NO SD
Yes	Yes	32	1.043	0.802	17.739	22.571	2.545	0.996
Yes	No	42	1.417	0.816	31.434	23.288	2.282	0.919
No	Yes	20	1.108	0.425	16.200	8.267	2.189	1.049
No	No	6	2.300	2.263	13.612	10.871	2.448	1.054

[a] FTP = federal emission certification test procedure

[b] SD = standard deviation

Table 68b. Associated Tests of Significance

Emission	Equality of Means: F-Value[a]	Equality of Means: Level of Significance	Homogeneity of Variance: Bartlett Test	Homogeneity of Variance: Approximate Level of Significance
HC	3.930	0.011	32.607	0.0
CO	4.271	0.007	23.411	0.0
NO_x	0.693	0.559	0.577	0.906
Log_{10} (HC)	4.040	0.009	6.122	0.115
Log_{10} (CO)	4.647	0.005	5.881	0.128
Log_{10} (NO_x)	0.757	0.521	1.530	0.687

[a] Degrees of freedom are 3, 96

Table 69. Correlation Coefficient Summary by Emission Control System Type – Phoenix

Short Test	Catalyst/Air[a]	Test Mode	No. of Vehicles	ST/FTP[b] Correlation Coefficients[c]					
				HC	CO	NO_x	Log (HC)	Log (CO)	Log (NO_x)
Federal Short Cycle	Yes/Yes		32	0.92	0.93	0.86	0.90	0.81	0.81
	Yes/No		42	0.62	0.75	0.82	0.66	0.84	0.75
	No/Yes		20	0.51	0.22*	0.92	0.80	0.62	0.95
	No/No		6	-0.70*	0.83	0.94	-0.71*	0.75*	0.97
Federal Three-Mode	Yes/Yes	High speed	32	0.54	0.47	0.79	0.41	0.71	0.84
		Low speed	32	0.61	0.54	0.71	0.51	0.81	0.65
		Idle in neutral	32	0.73	0.96	0.17*	0.62	0.87	0.18*
		Idle in drive	25	0.87	0.96	-0.21*	0.79	0.87	-0.22*
	Yes/No	High speed	42	0.20*	0.31	0.68	0.22*	0.12*	0.66
		Low speed	42	0.25*	0.44	0.62	0.37	0.34	0.62
		Idle in neutral	42	0.63	0.73	-0.13*	0.80	0.71	-0.13*
		Idle in drive	37	0.66	0.73	-0.17*	0.78	0.74	-0.20*
	No/Yes	High speed	20	0.36*	0.38*	0.79	0.29*	0.48	0.77
		Low speed	20	0.34*	0.38*	0.86	0.16*	0.39*	0.80
		Idle in neutral	20	0.13*	0.45	0.05*	0.03*	0.35*	0.23*
		Idle in drive	10	0.55*	0.57*	0.41*	0.35*	0.86	0.57*
	No/No	High speed	6	-0.29*	-0.21*	0.70*	-0.16*	-0.17*	0.70*
		Low speed	6	-0.56*	0.07*	0.86	-0.58*	0.20*	0.86
		Idle in neutral	6	-0.92	0.58*	0.48*	-0.93	0.62*	0.63*
		Idle in drive	4	0.54*	0.38*	0.41*	0.57*	0.36*	0.57*

[a] Secondary air injection system

[b] ST/FTP = short test/federal emission certification test procedure

[c] Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

Table 70a. FTP Means and Standard Deviations by Fuel System Type — Phoenix

Fuel Injection	No. of Vehicles	FTP[a] Emission (gm/mi)					
		HC		CO		NO_x	
		Mean	SD[b]	Mean	SD	Mean	SD
Yes	10	1.527	1.934	15.068	13.934	1.700	0.703
No	90	1.262	0.760	23.809	21.932	2.431	0.975

[a] FTP = federal emission certification test procedure

[b] SD = standard deviation

Table 70b. Associated Tests of Significance

Emission	Equality of Means		Homogeneity of Variance	
	F-Value[a]	Level of Significance	Bartlett Test	Approximate Level of Significance
HC	0.731	0.395	23.128	0.0
CO	1.512	0.222	2.646	0.110
NO_x	5.304	0.023	1.470	0.234
$\log_{10}(HC)$	0.027	0.869	2.098	0.155
$\log_{10}(CO)$	2.858	0.094	0.165	0.690
$\log_{10}(NO_x)$	5.903	0.017	0.150	0.704

[a] Degrees of freedom are 1, 98

Table 71. Correlation Coefficient Summary by Fuel System Type – Phoenix

Short Test	Fuel System Type	Test Mode	No. of Vehicles	ST/FTP[a] Correlation Coefficients[b]					
				HC	CO	NO_x	Log (HC)	Log (CO)	Log (NO_x)
Federal Short Cycle	Fuel Injection		10	0.24*	0.88	0.50*	0.67	0.90	0.50*
	Carburetion		90	0.58	0.76	0.86	0.75	0.80	0.83
Federal Three-Mode	Fuel Injection	High speed	10	0.05*	0.60*	0.83	0.28*	0.55*	0.79
		Low speed	10	0.01*	0.13*	0.75	0.19*	0.53*	0.71
		Idle in neutral	10	-0.05*	0.68	-0.11	0.22*	0.70	-0.15*
		Idle in drive	4	0.73	-0.18*	0.09*	0.36*	0.64*	0.26*
	Carburetion	High speed	90	0.32	0.34	0.72	0.27	0.21	0.71
		Low speed	90	0.36	0.42	0.64	0.36	0.38	0.64
		Idle in neutral	90	0.62	0.81	0.10*	0.67	0.75	0.14*
		Idle in drive	72	0.71	0.82	-0.07*	0.77	0.79	0.01*

[a] ST/FTP = short test/federal emission certification test procedure

[b] Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

Table 72a. FTP Means and Standard Deviations by Transmission Type — Phoenix

Transmission Type	No. of Vehicles	FTP[a] Emission (gm/mi)					
		HC		CO		NO_x	
		Mean	SD[b]	Mean	SD	Mean	SD
Automatic	76	1.246	0.725	24.771	22.564	2.529	0.931
Manual	24	1.423	1.409	17.118	16.143	1.813	0.921

[a] FTP = federal emission certification test procedure

[b] SD = standard deviation

Table 72b. Associated Tests of Significance

Emission	Equality of Means		Homogeneity of Variance	
	F-Value[a]	Level of Significance	Bartlett Test	Approximate Level of Significance
HC	0.661	0.418	18.597	0.0
CO	2.370	0.127	3.480	0.064
NO_x	10.848	0.001	0.004	0.948
$Log_{10}(HC)$	0.001	0.978	2.91	0.091
$Log_{10}(CO)$	2.111	0.149	0.680	0.413
$Log_{10}(NO_x)$	15.789	0.0	2.108	0.150

[a] Degrees of freedom are 1, 98

Table 73. Correlation Coefficient Summary by Transmission Type - Phoenix

Short Test	Transmission Type	Test Mode	No. of Vehicles	ST/FTP[a] Correlation Coefficients[b]					
				HC	CO	NO_x	Log (HC)	Log (CO)	Log (NO_x)
Federal Short Cycle	Automatic		76	0.72	0.82	0.83	0.76	0.82	0.80
	Manual		24	0.19*	0.53	0.89	0.67	0.74	0.79
	Automatic	High speed	76	0.24	0.26	0.74	0.25	0.20*	0.69
		Low speed	76	0.29	0.38	0.64	0.35	0.36	0.62
		Idle in neutral	76	0.65	0.81	0.13*	0.71	0.75	0.16*
		Idle in drive	76	0.71	0.81	0.05*	0.75	0.78	0.03*
	Manual	High speed	24	0.29*	0.73	0.89	0.32*	0.41	0.88
		Low speed	24	0.29*	0.73	0.77	0.32*	0.53	0.85
		Idle in neutral	24	0.18*	0.75	-0.12*	0.38*	0.68	-0.05*
		Idle in drive	--	----	----	----	----	----	----

[a] ST/FTP = short test/federal emission certification test procedure

[b] Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

Table 74a. FTP Means and Standard Deviations by Manufacturer — Phoenix

Manufacturer	No. of Vehicles	FTP(a) Emission (gm/mi)					
		HC		CO		NO_x	
		Mean	SD(b)	Mean	SD	Mean	SD
General Motors	33	1.233	0.790	25.527	22.299	2.423	0.929
Ford	20	1.280	0.853	24.451	26.279	2.502	0.820
Chrysler	12	1.761	0.732	41.495	22.679	2.678	1.084
American Motors	6	0.962	0.563	9.833	5.113	2.945	0.886
Others	29	1.228	1.208	13.969	9.749	1.929	0.990

(a) FTP = federal emission certification test procedure

(b) SD = standard deviation

Table 74b. Associated Tests of Significance

Emission	Equality of Means		Homogeneity of Variance	
	F-Value(a)	Level of Significance	Bartlett Test	Approximate Level of Significance
HC	1.019	0.402	9.349	0.060
CO	4.918	0.001	32.471	0.0
NO_x	2.579	0.042	1.340	0.862
$Log_{10}(HC)$	2.092	0.088	6.138	0.204
$Log_{10}(CO)$	4.778	0.002	3.495	0.496
$Log_{10}(NO_x)$	3.898	0.006	7.844	0.108

(a) Degrees of freedom are 4, 95

Table 75. Correlation Coefficient Summary by Manufacturer – Phoenix

Short Test	Manufacturer	Test Mode	No. of Vehicles	ST/FTP[a] Correlation Coefficients[b]					
				HC	CO	NO_x	Log (HC)	Log (CO)	Log (NO_x)
Federal Short Cycle	General Motors		33	0.80	0.82	0.93	0.85	0.87	0.90
	Ford		20	0.94	0.97	0.95	0.88	0.85	0.91
	Chrysler		12	-0.01*	0.72	0.94	0.01*	0.86	0.90
	American Motors Company		6	0.95	0.89	0.91	0.98	0.88	0.95
	Others		29	0.17*	0.34*	0.78	0.73	0.73	0.72
Federal Three-Mode	General Motors	High speed	33	0.25*	0.40	0.60	0.23*	0.20*	0.61
		Low speed	33	0.32*	0.59	0.67	0.42	0.56	0.66
		Idle in neutral	33	0.75	0.77	-0.02*	0.84	0.80	-0.04*
		Idle in drive	31	0.83	0.77	-0.22*	0.84	0.83	-0.28*
	Ford	High speed	20	0.60	0.41*	0.87	0.44*	0.58	0.82
		Low speed	20	0.64	0.49	0.73	0.52	0.67	0.62
		Idle in neutral	20	0.78	0.96	-0.26*	0.66	0.79	-0.27*
		Idle in drive	17	0.85	0.96	-0.47*	0.74	0.80	-0.52
	Chrysler	High speed	12	-0.05*	0.30*	0.91	0.03*	0.31*	0.88
		Low speed	12	-0.09*	0.22*	0.59	0.02*	0.27*	0.60
		Idle in neutral	12	0.19*	0.66	0.36*	0.38*	0.62	0.44*
		Idle in drive	12	0.13*	0.72	0.34*	0.30*	0.66	0.37*
	AMC	High speed	6	0.69*	0.45*	0.82	0.59*	0.73*	0.88
		Low speed	6	0.89	0.87	0.77*	0.95	0.90	0.80*
		Idle in neutral	6	0.96	0.96	0.28*	0.96	0.98	0.46*
		Idle in drive	5	0.99	1.00	-0.38*	1.00	0.97	-0.33*
	Others	High speed	29	0.13*	0.63	0.82	0.26*	0.61	0.83
		Low speed	29	0.13*	0.34*	0.86	0.26*	0.55	0.84
		Idle in neutral	29	0.05*	0.62	0.04*	0.23*	0.61	0.09*
		Idle in drive	11	0.68	0.32*	0.59*	0.54*	0.79	0.68

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[a] ST/FTP = short test/federal emission certification test procedure

[b] Correlation coefficients are statistically significant at the 95 percent confidence level except where indicated by an asterisk

Table 76. Comparison of ST HC Results by City — Predicted Population, Bounded Errors of Commission Method (E_c Set at 5 Percent)

Short Test	City	Test Mode	No. of Vehicles	Parameter (percent)			STE[a]
				E_c	E_o	FF	
Federal Short Cycle	All		300	5.0	13.0	18.7	0.589
	Chicago		100	4.2	12.7	15.8	0.554
	Houston		100	4.0	11.4	25.5	0.691
	Phoenix		100	6.3	13.6	15.3	0.530
Federal Three-Mode	All	High speed	300	5.0	26.2	5.4	0.172
		Low speed		5.0	24.1	7.5	0.237
		Idle in drive		5.0	19.8	11.9	0.375
		Idle in neutral		5.0	21.0	10.7	0.338
	Chicago	High speed	100	8.4	20.6	7.5	0.266
		Low speed		6.9	19.5	8.5	0.303
		Idle in drive		8.1	16.9	11.5	0.405
		Idle in neutral		7.5	18.4	10.0	0.352
	Houston	High speed	100	1.3	33.7	3.3	0.088
		Low speed		1.3	31.0	6.0	0.161
		Idle in drive		2.2	23.6	13.3	0.360
		Idle in neutral		3.2	24.1	12.8	0.348
	Phoenix	High speed	100	5.8	24.0	4.9	0.171
		Low speed		7.5	21.8	7.1	0.246
		Idle in drive		4.3	18.8	10.1	0.349
		Idle in neutral		3.6	20.3	8.5	0.296

[a] Short Test Effectiveness = $\frac{\%\ \text{FF for short test}}{\%\ \text{FTP failures in same population}}$

Table 77. Comparison of ST CO Results by City — Predicted Population, Bounded Errors of Commission Method (E_c Set at 5 Percent)

Short Test	City	Test Mode	No. of Vehicles	Parameter (percent)			STE[a]
				E_c	E_o	FF	
Federal Short Cycle	All		300	5.0	16.7	37.1	0.690
	Chicago		100	4.6	19.0	37.6	0.664
	Houston		100	4.1	14.4	39.1	0.731
	Phoenix		100	5.9	16.9	35.1	0.676
Federal Three-Mode	All	High speed	300	5.0	44.4	10.6	0.193
		Low speed		5.0	40.7	14.4	0.261
		Idle in drive		5.0	24.4	31.4	0.562
		Idle in neutral		5.0	26.6	29.3	0.524
	Chicago	High speed	100	5.4	40.9	15.7	0.277
		Low speed		5.8	37.9	18.7	0.330
		Idle in drive		6.9	26.3	30.8	0.539
		Idle in neutral		6.8	28.0	29.1	0.509
	Houston	High speed	100	3.7	48.6	8.2	0.145
		Low speed		4.4	43.4	13.7	0.239
		Idle in drive		4.5	24.5	34.4	0.584
		Idle in neutral		4.5	27.5	31.7	0.536
	Phoenix	High speed	100	4.5	43.6	8.3	0.160
		Low speed		3.8	41.2	10.7	0.206
		Idle in drive		3.8	23.4	28.6	0.551
		Idle in neutral		3.7	25.1	26.8	0.517

[a] Short Test Effectiveness = $\frac{\text{\% FF for short test}}{\text{\% FTP failures in same population}}$

Table 78. Comparison of ST NO_x Results by City — Predicted Population, Bounded Errors of Commission Method (E_c Set at 5 Percent)

Short Test	City	Test Mode	No. of Vehicles	Parameter (percent)			STE[a]
				E_c	E_o	FF	
Federal Short Cycle	All		300	5.0	8.4	12.8	0.604
	Chicago		100	4.2	7.5	12.1	0.618
	Houston		100	4.4	10.3	13.3	0.562
	Phoenix		100	6.4	7.2	13.0	0.645
Federal Three-Mode	All	High speed	300	5.0	14.6	6.6	0.310
		Low speed		5.0	14.8	6.4	0.301
		Idle in drive		5.0	17.6	3.5	0.167
		Idle in neutral		5.0	18.4	2.8	0.130
	Chicago	High speed	100	3.2	15.6	4.0	0.204
		Low speed		3.1	16.1	3.5	0.177
		Idle in drive		5.4	16.5	3.1	0.159
		Idle in neutral		5.7	16.4	3.1	0.158
	Houston	High speed	100	4.2	17.7	5.9	0.249
		Low speed		4.5	16.7	6.9	0.291
		Idle in drive		3.8	18.4	5.2	0.221
		Idle in neutral		4.9	19.7	3.9	0.166
	Phoenix	High speed	100	6.8	9.4	10.8	0.535
		Low speed		7.1	10.7	9.5	0.471
		Idle in drive		5.2	18.0	2.2	0.108
		Idle in neutral		2.9	19.2	1.0	0.049

[a] Short Test Effectiveness $= \frac{\text{\% FF for short test}}{\text{\% FTP failures in same population}}$

Table 79. Comparison of ST Multiple Constituent Results by City – Actual Population, Bounded Errors of Commission Method (E_c Set at 5 Percent)

Short Test	City	Test Mode	No. of Vehicles	Parameter (percent)			STE[a]
				E_c	E_o	FF	
Federal Short Cycle	All		300	7.0	11.7	53.7	0.821
	Chicago		100	10.0	12.0	54.0	0.818
	Houston		100	4.0	11.0	55.0	0.833
	Phoenix		100	7.0	12.0	52.0	0.813
Federal Three-Mode	All	High speed	300	3.3	42.7	22.7	0.348
		Low speed		6.3	37.0	28.3	0.429
		Idle in drive		6.3	19.3	46.0	0.704
		Idle in neutral		4.7	26.3	39.0	0.597
		Best[b]		4.3	22.0	43.3	0.663
	Chicago	High speed	100	5.0	44.0	22.0	0.333
		Low speed		10.0	36.0	30.0	0.455
		Idle in drive		8.0	23.0	43.0	0.652
		Idle in neutral		7.0	28.0	38.0	0.576
		Best[b]		6.0	26.0	40.0	0.606
	Houston	High speed	100	1.0	46.0	20.0	0.303
		Low speed		1.0	40.0	26.0	0.394
		Idle in drive		6.0	15.0	51.0	0.773
		Idle in neutral		3.0	24.0	42.0	0.636
		Best[b]		3.0	18.0	48.0	0.727
	Phoenix	High speed	100	4.0	38.0	26.0	0.406
		Low speed		8.0	35.0	29.0	0.453
		Idle in drive		5.0	20.0	44.0	0.688
		Idle in neutral		4.0	27.0	37.0	0.578
		Best[b]		4.0	22.0	42.0	0.656

[a] Short Test Effectiveness = $\frac{\text{\% FF for short test}}{\text{\% FTP failures in same population}}$

[b] Best mode is: HC and CO at idle in drive
NO_x at high speed

Table 80. Comparison of ST HC Results by Inertia Weight — Predicted Population, Three Cities, Bounded Errors of Commission Method (E_c Set at 5 Percent)

Short Test	Inertia Test Weight Group (lb)	Test Mode	No. of Vehicles	Parameter (percent)			STE[(a)]
				E_c	E_o	FF	
Federal Short Cycle	All		300	5.0	13.0	18.7	0.589
	0 to 2500		50	3.5	19.0	14.4	0.431
	2501 to 3500		119	4.5	11.4	17.6	0.606
	3501 to 4500		98	4.5	9.3	18.7	0.667
	4501 and greater		33	8.3	21.1	28.6	0.575
Federal Three-Mode	All	High speed	300	5.0	26.1	5.4	0.172
		Low speed		5.0	24.1	7.5	0.237
		Idle in drive		5.0	19.8	11.9	0.375
		Idle in neutral		5.0	21.0	10.7	0.338
	0 to 2500	High speed	50	9.5	22.0	11.0	0.340
		Low speed		7.5	21.5	12.0	0.357
		Idle in drive		4.4	24.0	9.8	0.293
		Idle in neutral		4.2	25.0	8.9	0.265
	2501 to 3500	High speed	119	4.5	24.6	4.4	0.151
		Low speed		5.5	21.3	7.6	0.264
		Idle in drive		6.6	16.3	12.7	0.439
		Idle in neutral		5.5	19.0	10.0	0.344
	3501 to 4500	High speed	98	5.6	22.3	5.3	0.192
		Low speed		4.5	22.1	5.5	0.200
		Idle in drive		4.2	18.5	9.5	0.340
		Idle in neutral		5.0	18.7	9.3	0.333
	4501 and greater	High speed	33	0.0	60.6	0.01	0.000
		Low speed		1.1	43.8	5.9	0.119
		Idle in drive		2.3	30.6	19.1	0.385
		Idle in neutral		3.9	29.4	20.3	0.408

(a) Short Test Effectiveness = $\frac{\text{\% FF for short test}}{\text{\% FTP failures in same population}}$

Table 81. Comparison of ST CO Results by Inertia Weight — Predicted Population, Three Cities, Bounded Errors of Commission Method (E_c Set at 5 Percent)

Short Test	Inertia Test Weight Group (lb)	Test Mode	No. of Vehicles	Parameter (percent)			STE[a]
				E_c	E_o	FF	
Federal Short Cycle	All		300	5.0	16.7	37.1	0.690
	0 to 2500		50	13.1	10.7	26.9	0.715
	2501 to 3500		119	4.6	16.5	32.6	0.663
	3501 to 4500		98	3.1	16.0	40.8	0.718
	4501 and greater		33	2.3	22.3	53.1	0.705
Federal Three-Mode	All	High speed	300	5.0	44.4	10.6	0.193
		Low speed		5.0	40.7	14.4	0.261
		Idle in drive		5.0	12.4	31.4	0.562
		Idle in neutral		5.0	26.6	29.3	0.524
	0 to 2500	High speed	50	12.6	19.5	18.0	0.483
		Low speed		14.2	21.0	16.7	0.443
		Idle in drive		14.6	15.8	22.0	0.583
		Idle in neutral		14.5	17.8	20.0	0.528
	2501 to 3500	High speed	119	4.2	42.7	7.3	0.146
		Low speed		3.9	37.1	12.7	0.255
		Idle in drive		5.6	19.3	31.0	0.617
		Idle in neutral		5.8	22.4	28.2	0.557
	3501 to 4500	High speed	98	2.8	48.7	10.4	0.175
		Low speed		3.2	45.8	13.8	0.231
		Idle in drive		2.0	27.9	31.8	0.533
		Idle in neutral		1.6	30.0	30.1	0.500
	4501 and greater	High speed	33	1.9	63.4	14.0	0.181
		Low speed		1.7	59.2	18.2	0.235
		Idle in drive		1.0	40.2	41.7	0.509
		Idle in neutral		6.1	12.3	65.5	0.838

[a] Short Test Effectiveness = $\frac{\text{\% FF for short test}}{\text{\% FTP failures in same population}}$

Table 82. Comparison of ST NO_x Results by Inertia Weight — Predicted Population, Three Cities, Bounded Errors of Commission Method (E_c Set at 5 Percent)

Short Test	Inertia Test Weight Group (lb)	Test Mode	No. of Vehicles	Parameter (percent)			STE[(a)]
				E_c	E_o	FF	
Federal Short Cycle	All		300	5.0	8.4	12.8	0.604
	0 to 2500		50	0.8	4.0	1.3	0.251
	2501 to 3500		119	4.5	9.1	14.7	0.618
	3501 to 4500		98	5.9	9.5	14.3	0.602
	4501 and greater		33	5.1	7.8	11.0	0.585
Federal Three-Mode	All	High speed	300	5.0	14.6	6.6	0.310
		Low speed		5.0	14.8	6.4	0.301
		Idle in drive		5.0	17.2	3.5	0.167
		Idle in neutral		5.0	18.4	2.8	0.130
	0 to 2500	High speed	50	13.2	2.4	3.0	0.552
		Low speed		3.9	4.0	1.3	0.250
		Idle in drive		0.0	5.3	0.0	0.000
		Idle in neutral		4.3	5.0	0.4	0.066
	2501 to 3500	High speed	119	4.2	16.3	7.5	0.315
		Low speed		5.4	13.9	10.0	0.417
		Idle in drive		5.9	19.2	4.7	0.195
		Idle in neutral		3.4	23.5	1.00	0.157
	3501 to 4500	High speed	98	2.6	18.7	5.1	0.214
		Low speed		3.9	19.3	4.6	0.191
		Idle in drive		6.2	20.9	2.9	0.124
		Idle in neutral		1.4	22.8	1.0	0.044
	4501 and greater	High speed	33	1.3	16.6	2.1	0.114
		Low speed		1.6	17.0	1.8	0.095
		Idle drive		4.7	16.0	2.9	0.152
		Idle in neutral		0.01	18.7	0.02	0.000

(a) Short Test Effectiveness = $\frac{\text{\% FF for short test}}{\text{\% FTP failures in same population}}$

Table 83. Comparison of ST Multiple Constituent Results by Inertia Weight — Actual Population, Three Cities, Bounded Errors of Commission Method (E_c Set at 5 Percent)

Short Test	Inertia Test Weight Group (lb)	Test Mode	No. of Vehicles	Parameter (percent)			STE[(a)]
				E_c	E_o	FF	
Federal Short Cycle	All		300	7.0	11.7	53.7	0.821
	0 to 2500		50	10.0	6.0	40.0	0.870
	2501 to 3500		119	6.7	16.0	49.6	0.756
	3501 to 4500		98	6.1	10.2	60.2	0.855
	4501 and greater		33	6.1	9.1	69.7	0.885
Federal Three-Mode	All	High speed	300	3.3	42.7	3.3	0.072
		Low speed		6.3	37.0	28.3	0.433
		Idle in drive		6.3	19.3	46.0	0.704
		Idle in neutral		4.7	26.3	39.0	0.597
		Best(b)		4.3	22.0	43.3	0.663
	0 to 2500	High speed		16.0	20.0	26.0	0.565
		Low speed		26.0	18.0	28.0	0.609
		Idle in drive		10.0	14.0	32.0	0.696
		Idle in neutral		12.0	14.0	32.0	0.696
		Best(b)		12.0	12.0	34.0	0.739
	2501 to 3500	High speed	119	1.7	42.0	23.5	0.359
		Low speed		3.4	35.3	30.2	0.461
		Idle in drive		7.6	15.0	50.4	0.771
		Idle in neutral		5.0	26.0	40.0	0.606
		Best(b)		4.2	17.6	48.0	0.732
	3501 to 4500	High speed	98	0.0	51.0	19.4	0.276
		Low speed		2.0	43.9	26.5	0.376
		Idle in drive		5.1	25.5	44.9	0.637
		Idle in neutral		2.0	33.7	36.7	0.521
		Best(b)		2.0	30.6	39.8	0.565
	4501 and greater	High speed	33	0.0	54.5	24.2	0.307
		Low speed		0.0	51.5	27.3	0.346
		Idle in drive		0.0	24.2	54.6	0.693
		Idle in neutral		0.0	24.2	54.5	0.692
		Best(b)		0.0	27.2	51.5	0.654

(a) Short Test Effectiveness = $\frac{\text{\% FF for short test}}{\text{\% FTP failures in same population}}$

(b) Best mode is: HC and CO at idle in drive
NO_x at high speed

Table 84. Comparison of ST HC Results by Displacement — Predicted Population, Three Cities, Bounded Errors of Commission Method (E_C Set at 5 Percent)

Short Test	CID[a] Group	Test Mode	No. of Vehicles	Parameter (percent)			STE[b]
				E_c	E_o	FF	
Federal Short Cycle	All		300	5.0	13.0	18.7	0.589
	0 to 150		95	4.6	13.5	18.6	0.579
	151 to 259		54	4.6	14.4	12.8	0.471
	260 and greater		151	5.3	12.1	20.8	0.632
Federal Three-Mode	All	High speed	300	5.0	26.1	5.4	0.172
		Low speed		5.0	24.1	7.5	0.237
		Idle in drive		5.0	19.8	11.9	0.375
		Idle in neutral		5.0	21.0	10.7	0.338
	0 to 150	High speed	95	7.3	25.3	20.0	0.258
		Low speed		7.0	22.0	10.1	0.315
		Idle in drive		7.1	19.6	12.6	0.319
		Idle in neutral		5.7	22.7	9.4	0.293
	151 to 259	High speed	54	4.9	23.6	3.6	0.133
		Low speed		7.9	19.1	8.2	0.300
		Idle in drive		7.1	16.9	10.3	0.380
		Idle in neutral		6.8	18.5	8.8	0.323
	260 and greater	High speed	151	3.6	28.3	4.3	0.133
		Low speed		2.9	27.2	5.5	0.168
		Idle in drive		3.2	21.2	11.7	0.356
		Idle in neutral		4.1	20.9	12.0	0.366

(a) CID = cubic inch displacement

(b) Short Test Effectiveness $= \frac{\text{\% FF for short test}}{\text{\% FTP failures in same population}}$

Table 85. Comparison of ST CO Results by Displacement — Predicted Population, Three Cities, Bounded Errors of Commission Method (E_c Set at 5 Percent)

Short Test	CID[a] Group	Test Mode	No. of Vehicles	Parameter (percent)			STE[b]
				E_c	E_o	FF	
Federal Short Cycle	All		300	5.0	16.7	37.1	0.690
	0 to 150		95	12.5	10.2	34.5	0.773
	151 to 259		54	2.7	20.5	35.0	0.631
	260 and greater		151	2.7	18.6	38.5	0.674
Federal Three-Mode	All	High speed	300	5.0	44.4	10.6	0.193
		Low speed		5.0	40.7	14.4	0.261
		Idle in drive		5.0	12.4	31.4	0.562
		Idle in neutral		5.0	26.6	29.3	0.524
	0 to 150	High speed	95	11.0	31.6	13.1	0.293
		Low speed		10.4	27.8	17.0	0.379
		Idle in drive		12.5	16.2	28.6	0.639
		Idle in neutral		12.1	19.0	25.8	0.576
	151 to 259	High speed	54	3.9	53.4	5.1	0.087
		Low speed		3.7	47.9	11.1	0.188
		Idle in drive		5.0	24.7	34.8	0.585
		Idle in neutral		6.2	29.2	30.2	0.508
	260 and greater	High speed	151	2.4	48.5	10.2	0.174
		Low speed		2.5	45.4	13.4	0.228
		Idle in drive		1.8	28.8	31.1	0.519
		Idle in neutral		1.7	30.3	29.8	0.496

[a] CID = cubic inch displacement

[b] Short Test Effectiveness = $\frac{\text{\% FF for short test}}{\text{\% FTP failures in same population}}$

Table 86. Comparison of ST NO_x Results by Displacement—Predicted Population, Three Cities, Bounded Errors of Commission Method (E_c Set at 5 Percent)

Short Test	CID[a] Group	Test Mode	No. of Vehicles	Parameter (percent)			STE[b]
				E_c	E_o	FF	
Federal Short Cycle	All		300	5.0	8.4	12.8	0.604
	0 to 150		95	3.1	7.3	8.2	0.530
	151 to 259		54	5.0	7.5	12.5	0.626
	260 and greater		151	6.7	9.9	14.9	0.600
Federal Three-Mode	All	High speed	300	5.0	14.6	6.6	0.310
		Low speed		5.0	14.8	6.4	0.301
		Idle in drive		5.0	17.2	3.5	0.167
		Idle in neutral		5.0	18.4	2.8	0.130
	0 to 150	High speed	95	9.9	6.5	9.0	0.578
		Low speed		4.7	9.2	5.0	0.355
		Idle in drive		1.2	14.6	1.0	0.062
		Idle in neutral		1.0	14.0	0.2	0.016
	151 to 259	High speed	54	2.8	17.0	3.1	0.154
		Low speed		3.5	12.6	7.4	0.372
		Idle in drive		10.1	14.4	5.6	0.280
		Idle in neutral		10.3	15.4	4.5	0.228
	260 and greater	High speed	151	2.8	18.8	6.0	0.242
		Low speed		4.6	19.7	5.1	0.206
		Idle in drive		6.5	20.7	4.0	0.163
		Idle in neutral		3.3	21.9	2.8	0.115

[a] CID = cubic inch displacement

[b] Short Test Effectiveness = $\frac{\text{\% FF for short test}}{\text{\% FTP failures in same population}}$

Table 87. Comparison of ST Multiple Constituent Results by Displacement – Predicted Population, Three Cities, Bounded Errors of Commission Method (E_c Set at 5 Percent)

Short Test	CID[a] Group	Test Mode	No. of Vehicles	Parameter (percent)			STE[b]
				E_c	E_o	FF	
Federal Short Cycle	All		300	7.0	11.7	53.7	0.821
	0 to 150		95	8.4	12.6	45.3	0.782
	151 to 259		54	1.9	13.0	55.6	0.950
	260 and greater		151	8.0	10.6	58.3	0.846
Federal Three-Mode	All	High speed	300	3.3	42.7	3.3	0.072
		Low speed		6.3	37.0	28.3	0.433
		Idle in drive		6.3	19.3	46.0	0.704
		Idle in neutral		4.7	26.3	39.0	0.597
		Best[c]		4.3	22.0	43.3	0.663
	0 to 150	High speed	95	9.5	27.4	30.5	0.527
		Low speed		16.8	27.4	30.5	0.527
		Idle in drive		8.4	14.7	43.2	0.746
		Idle in neutral		9.5	20.0	37.9	0.655
		Best[c]		10.5	12.6	45.3	0.782
	151 to 259	High speed	54	1.8	55.6	13.0	0.190
		Low speed		1.8	40.7	27.8	0.406
		Idle in drive		9.3	18.5	50.0	0.729
		Idle in neutral		5.6	33.3	35.2	0.514
		Best[c]		1.8	25.9	42.6	0.622
	260 and greater	High speed	151	0.0	47.7	21.2	0.308
		Low speed		1.3	41.7	27.1	0.394
		Idle in drive		4.0	22.5	46.4	0.673
		Idle in neutral		1.3	27.8	41.0	0.596
		Best[c]		1.3	26.5	42.4	0.615

[a] CID = cubic inch displacement

[b] Short Test Effectiveness = $\frac{\text{\% FF for short test}}{\text{\% FTP failures in same population}}$

[c] Best mode is: HC and CO at idle in drive
NO_x at high speed

Table 88. Comparison of ST HC Results by Emission Controls Type — Predicted Population, Three Cities, Bounded Errors of Commission Method (E_c Set at 5 Percent)

Short Test	Emission Controls Catalyst/Air[a]	Test Mode	No. of Vehicles	Parameter (percent) E_c	E_o	FF	STE[b]
Federal Short Cycle	All		300	5.0	13.0	18.7	0.589
	Yes/Yes		89	3.2	8.6	11.4	0.570
	Yes/No		127	4.5	14.7	22.3	0.602
	No/Yes		59	7.5	10.7	18.9	0.639
	No/No		25	4.7	34.0	20.4	0.376
Federal Three-Mode	All	High speed	300	5.0	26.1	5.4	0.172
		Low speed		5.0	24.1	7.5	0.237
		Idle in drive		5.0	19.8	11.9	0.375
		Idle in neutral		5.0	21.0	10.7	0.338
	Yes/Yes	High speed	89	4.7	15.9	3.6	0.183
		Low speed		4.5	15.6	3.8	0.197
		Idle in drive		3.5	17.0	3.0	0.149
		Idle in neutral		3.5	17.2	2.7	0.136
	Yes/No	High speed	127	3.4	33.0	3.9	0.106
		Low speed		2.8	30.4	6.6	0.179
		Idle in drive		4.6	18.3	18.6	0.504
		Idle in neutral		5.5	18.6	18.4	0.498
	No/Yes	High speed	59	7.1	21.2	8.4	0.285
		Low speed		8.0	20.3	9.3	0.315
		Idle in drive		5.4	20.1	9.5	0.321
		Idle in neutral		3.5	24.5	5.1	0.172
	No/No	High speed	25	8.8	40.1	14.3	0.263
		Low speed		9.3	32.1	22.3	0.410
		Idle in drive		6.8	35.3	19.1	0.352
		Idle in neutral		5.3	37.2	17.2	0.316

[a] Secondary air injection system

[b] Short Test Effectiveness = $\frac{\text{\% FF for short test}}{\text{\% FTP failures in same population}}$

Table 89. Comparison of ST CO Results by Emission Controls Type – Predicted Population, Three Cities, Bounded Errors of Commission Method (E_c Set at 5 Percent)

Short Test	Emission Controls Catalyst/Air[a]	Test Mode	No. of Vehicles	Parameter (percent) E_c	E_o	FF	STE[b]
Federal Short Cycle	All		300	5.0	16.7	37.1	0.690
	Yes/Yes		89	4.8	14.3	25.6	0.642
	Yes/No		127	2.1	20.0	46.7	0.700
	No/Yes		59	17.0	7.3	34.1	0.823
	No/No		25	8.1	15.1	33.8	0.691
Federal Three-Mode	All	High speed	300	5.0	44.4	10.6	0.193
		Low speed		5.0	40.7	14.4	0.261
		Idle in drive		5.0	12.4	31.4	0.562
		Idle in neutral		5.0	26.6	29.3	0.524
	Yes/Yes	High speed	89	2.1	31.1	10.4	0.250
		Low speed		3.0	27.2	14.2	0.344
		Idle in drive		2.5	22.0	20.1	0.478
		Idle in neutral		2.5	24.2	18.0	0.425
	Yes/No	High speed	127	2.1	59.2	8.8	0.129
		Low speed		1.6	56.0	12.7	0.185
		Idle in drive		2.8	30.1	39.3	0.566
		Idle in neutral		3.2	32.0	37.9	0.543
	No/Yes	High speed	59	7.6	27.6	13.9	0.334
		Low speed		9.6	25.9	15.5	0.375
		Idle in drive		15.0	16.5	25.0	0.602
		Idle in neutral		13.3	22.1	19.3	0.467
	No/No	High speed	25	7.4	34.3	14.5	0.298
		Low speed		15.3	30.8	18.0	0.369
		Idle in drive		10.7	13.6	35.2	0.721
		Idle in neutral		9.2	13.3	35.4	0.725

(a) Secondary air injection system

(b) Short Test Effectiveness = $\frac{\text{\% FF for short test}}{\text{\% FTP failures in same population}}$

Table 90. Comparison of ST NO_x Results by Emission Controls Type — Predicted Population, Three Cities, Bounded Errors of Commission Method (E_c Set at 5 Percent)

Short Test	Emission Controls Catalyst/Air[a]	Test Mode	No. of Vehicles	Parameter (percent) E_c	E_o	FF	STE[b]
Federal Short Cycle	All		300	5.0	8.4	12.8	0.604
	Yes/Yes		89	3.8	14.8	20.6	0.582
	Yes/No		127	7.2	6.3	9.6	0.602
	No/Yes		59	1.4	8.8	9.6	0.522
	No/No		25	3.9	4.2	9.7	0.696
Federal Three-Mode	All	High speed	300	5.0	14.6	6.6	0.310
		Low speed		5.0	14.8	6.4	0.301
		Idle in drive		5.0	17.2	3.5	0.167
		Idle in neutral		5.0	18.4	2.8	0.130
	Yes/Yes	High speed	89	1.9	21.8	8.6	0.283
		Low speed		1.3	25.6	4.8	0.158
		Idle in drive		4.7	25.6	4.8	0.157
		Idle in neutral		4.2	27.6	2.7	0.090
	Yes/No	High speed	127	5.4	11.5	4.4	0.279
		Low speed		8.1	9.6	6.3	0.395
		Idle in drive		8.7	12.8	3.1	0.195
		Idle in neutral		6.7	13.5	2.4	0.153
	No/Yes	High speed	59	6.6	9.3	9.1	0.495
		Low speed		3.6	10.0	8.3	0.451
		Idle in drive		0.5	17.1	1.3	0.068
		Idle in neutral		0.03	19.6	0.04	0.002
	No/No	High speed	25	12.9	11.3	2.6	0.188
		Low speed		6.2	10.5	3.4	0.244
		Idle in drive		2.8	10.4	3.6	0.256
		Idle in neutral		4.9	10.7	3.2	0.230

[a] Secondary air injection system

[b] Short Test Effectiveness = $\frac{\text{\% FF for short test}}{\text{\% FTP failures in same population}}$

Table 91. Comparison of ST Multiple Constituent Results by Emission Controls Type – Predicted Population, Three Cities, Bounded Errors of Commission Method (E_c Set at 5 Percent)

Short Test	Emission Controls Catalyst/Air[a]	Test Mode	No. of Vehicles	Parameter (percent) E_c	E_o	FF	STE[b]
Federal Short Cycle	All		300	7.0	11.7	53.7	0.821
	Yes/Yes		89	10.1	13.5	43.8	0.764
	Yes/No		127	3.9	13.4	59.8	0.816
	No/Yes		59	5.1	8.5	54.2	0.864
	No/No		25	16.0	4.0	56.0	0.933
Federal Three-Mode	All	High speed	300	3.3	42.7	3.3	0.072
		Low speed		6.3	37.0	28.3	0.433
		Idle in drive		6.3	19.3	46.0	0.704
		Idle in neutral		4.7	26.3	39.0	0.597
		Best[c]		4.3	22.0	43.3	0.663
	Yes/Yes	High speed	89	1.12	38.2	19.1	0.333
		Low speed		5.6	38.2	19.1	0.333
		Idle in drive		3.4	30.3	27.0	0.471
		Idle in neutral		1.1	36.0	21.3	0.372
		Best[c]		3.4	30.3	27.0	0.471
	Yes/No	High speed	127	1.0	52.0	21.3	0.291
		Low speed		2.4	43.3	30.0	0.409
		Idle in drive		6.3	13.4	59.8	0.817
		Idle in neutral		3.9	19.7	53.5	0.731
		Best[c]		2.4	18.9	54.3	0.742
	No/Yes	High speed	59	6.8	32.2	30.5	0.486
		Low speed		10.2	30.5	32.2	0.514
		Idle in drive		8.5	18.6	44.1	0.703
		Idle in neutral		6.8	30.5	32.2	0.514
		Best[c]		8.5	20.3	42.4	0.676
	No/No	High speed	25	16.0	36.0	24.0	0.400
		Low speed		20.0	16.0	44.0	0.733
		Idle in drive		12.0	12.0	48.0	0.800
		Idle in neutral		16.0	16.0	44.0	0.733
		Best[c]		8.0	12.0	48.0	0.800

[a] Secondary air injection system

[b] Short Test Effectiveness = $\frac{\text{\% FF for short test}}{\text{\% FTP failures in same population}}$

[c] Best mode is: HC and CO at idle in drive; NO_x at high speed

Table 92. Comparison of ST HC Results by Fuel System Type — Predicted Population, Three Cities, Bounded Errors of Commission Method (E_c Set at 5 Percent)

Short Test	Fuel System Type	Test Mode	No. of Vehicles	Parameter (percent)			STE[a]
				E_c	E_o	FF	
Federal Short Cycle	All		300	5.0	13.0	18.7	0.589
	Fuel Injection		30	3.3	20.7	20.7	0.501
	Carburetion		270	5.2	12.3	18.4	0.600
Federal Three-Mode	All	High speed	300	5.0	26.1	5.4	0.172
		Low speed		5.0	24.1	7.5	0.237
		Idle in drive		5.0	19.8	11.9	0.375
		Idle in neutral		5.0	21.0	10.7	0.338
	Fuel Injection	High speed	30	10.7	26.0	15.3	0.370
		Low speed		11.9	24.0	17.4	0.420
		Idle in drive		7.0	24.8	16.6	0.401
		Idle in neutral		6.2	26.5	14.9	0.360
	Carburetion	High speed	270	4.3	26.1	4.4	0.145
		Low speed		4.3	24.2	6.4	0.209
		Idle in drive		4.8	19.3	11.3	0.370
		Idle in neutral		4.9	20.4	10.2	0.334

[a] Short test effectiveness = $\frac{\text{\% FF for short test}}{\text{\% FTP failures in same population}}$

Table 93. Comparison of ST CO Results by Fuel System Type — Predicted Population, Three Cities, Bounded Errors of Commission Method (E_c Set at 5 Percent)

Short Test	Fuel System Type	Test Mode	No. of Vehicles	Parameter (percent)			STE[a]
				E_c	E_o	FF	
Federal Short Cycle	All		300	5.0	16.7	37.1	0.690
	Fuel Injection		30	8.9	5.8	38.1	0.868
	Carburetion		270	4.4	17.4	37.3	0.682
Federal Three-Mode	All	High speed	300	5.0	44.4	10.6	0.193
		Low speed		5.0	40.7	14.4	0.261
		Idle in drive		5.0	12.4	31.4	0.562
		Idle in neutral		5.0	26.6	29.3	0.524
	Fuel Injection	High speed	30	9.3	23.3	20.6	0.470
		Low speed		12.2	22.1	21.8	0.495
		Idle in drive		13.2	9.6	34.3	0.781
		Idle in neutral		10.7	12.0	32.0	0.728
	Carburetion	High speed	270	4.1	46.3	9.8	0.175
		Low speed		4.1	42.5	13.7	0.244
		Idle in drive		4.1	25.8	31.2	0.458
		Idle in neutral		4.3	28.0	29.2	0.511

[a] Short Test Effectiveness $= \frac{\text{\% FF for short test}}{\text{\% FTP failures in same population}}$

Table 94. Comparison of ST NO_x Results by Fuel System Type — Predicted Population, Three Cities, Bounded Errors of Commission Method (E_c Set at 5 Percent)

Short Test	Fuel System Type	Test Mode	No. of Vehicles	Parameter (percent)			STE[a]
				E_c	E_o	FF	
Federal Short Cycle	All		300	5.0	8.4	12.8	0.604
	Fuel Injection		30	2.2	6.1	1.6	0.201
	Carburetion		270	5.1	8.4	14.2	0.629
Federal Three-Mode	All	High speed	300	5.0	14.6	6.6	0.310
		Low speed		5.0	14.8	6.4	0.301
		Idle in drive		5.0	17.2	3.5	0.167
		Idle in neutral		5.0	18.4	2.8	0.130
	Fuel Injection	High speed	30	5.3	2.9	2.1	0.426
		Low speed		6.9	5.6	2.1	0.271
		Idle in drive		0.16	7.7	0.01	0.001
		Idle in neutral		5.3	7.5	0.18	0.024
	Carburetion	High speed	270	4.6	15.7	6.8	0.301
		Low speed		4.8	15.7	6.9	0.305
		Idle in drive		5.5	18.3	4.2	0.187
		Idle in neutral		4.6	19.4	3.1	0.137

[a] Short Test Effectiveness = $\frac{\text{\% FF for short test}}{\text{\% FTP failures in same population}}$

Table 95. Comparison of ST Multiple Constituent Results by Fuel System Type — Predicted Population, Three Cities, Bounded Errors of Commission Method (E_c Set at 5 Percent)

Short Test	Fuel System Type	Test Mode	No. of Vehicles	Parameter (percent)			STE[a]
				E_c	E_o	FF	
Federal Short Cycle	All		300	7.0	11.7	53.7	0.821
	Fuel Injection		30	10.0	6.7	46.7	0.876
	Carburetion		270	6.7	12.2	54.4	0.816
Federal Three-Mode	All	High speed	300	3.3	42.7	3.3	0.072
		Low speed		6.3	37.0	28.3	0.433
		Idle in drive		6.3	19.3	46.0	0.704
		Idle in neutral		4.7	26.3	39.0	0.597
		Best[b]		4.3	22.0	43.3	0.663
	Fuel Injection	High speed	30	16.7	30.0	23.3	0.437
		Low speed		23.3	23.3	30.0	0.563
		Idle in drive		13.3	10.0	43.3	0.812
		Idle in neutral		16.7	13.3	40.0	0.751
		Best[b]		13.3	6.7	46.7	0.875
	Carburetion	High speed	270	1.8	44.0	22.6	0.339
		Low speed		4.4	38.5	28.1	0.422
		Idle in drive		5.6	20.4	46.3	0.694
		Idle in neutral		3.3	27.8	38.9	0.583
		Best[b]		3.3	23.7	43.0	0.645

(a) Short Test Effectiveness = $\frac{\text{\% FF for short test}}{\text{\% FTP failures in same population}}$

(b) Best mode is: HC and CO at idle in drive
NO_x at high speed

Table 96. Comparison of ST HC Results by Transmission Type — Predicted Population, Three Cities, Bounded Errors of Commission Method (E_c Set at 5 Percent)

Short Test	Transmission Type	Test Mode	No. of Vehicles	Parameter (percent)			STE[(a)]
				E_c	E_o	FF	
Federal Short Cycle	All		300	5.0	13.0	18.7	0.589
	Automatic		229	5.1	11.4	19.0	0.624
	Manual		71	4.8	18.9	17.4	0.481
Federal Three-Mode	All	High speed	300	5.0	26.1	5.4	0.172
		Low speed		5.0	24.1	7.5	0.237
		Idle in drive		5.0	19.8	11.9	0.375
		Idle in neutral		5.0	21.0	10.7	0.338
	Automatic	High speed	229	4.5	24.0	4.5	0.150
		Low speed		4.8	23.7	6.6	0.217
		Idle in drive		4.9	18.2	12.2	0.401
		Idle in neutral		4.9	19.8	10.6	0.348
	Manual	High speed	71	6.5	27.7	8.6	0.236
		Low speed		5.6	25.7	10.6	0.292
		Idle in drive		5.4	25.6	10.7	0.296
		Idle in neutral		5.6	25.3	10.9	0.301

(a) Short Test Effectiveness = $\frac{\text{\% FF for short test}}{\text{\% FTP failures in same population}}$

Table 97. Comparison of ST CO Results by Transmission Type Predicted Population, Three Cities, Bounded Errors of Commission Method (E_c Set at 5 Percent)

Short Test	Transmission Type	Test Mode	No. of Vehicles	Parameter (percent)			STE[a]
				E_c	E_o	FF	
Federal Short Cycle	All		300	5.0	16.7	37.1	0.690
	Automatic		229	3.4	18.1	38.0	0.678
	Manual		71	12.2	10.8	32.8	0.752
Federal Three-Mode	All	High speed	300	5.0	44.4	10.6	0.193
		Low speed		5.0	40.7	14.4	0.261
		Idle in drive		5.0	12.4	31.4	0.562
		Idle in neutral		5.0	26.6	29.3	0.524
	Automatic	High speed	229	3.5	47.6	10.1	0.175
		Low speed		3.4	44.5	13.4	0.231
		Idle in drive		3.6	26.1	32.7	0.556
		Idle in neutral		3.6	28.7	30.2	0.512
	Manual	High speed	71	10.8	32.4	11.2	0.257
		Low speed		10.1	26.2	17.4	0.399
		Idle in drive		10.8	18.3	25.4	0.582
		Idle in neutral		10.7	18.4	25.3	0.578

[a] Short Test Effectiveness = $\frac{\text{\% FF for short test}}{\text{\% FTP failures in same population}}$

Table 98. Comparison of ST NO_x Results by Transmission Type — Predicted Population, Three Cities, Bounded Errors of Commission Method (E_c Set at 5 Percent)

Short Test	Transmission Type	Test Mode	No. of Vehicles	Parameter (percent)			STE[(a)]
				E_c	E_o	FF	
Federal Short Cycle	All		300	5.0	8.4	12.8	0.604
	Automatic		229	5.6	9.4	14.7	0.610
	Manual		71	1.0	6.3	3.2	0.334
Federal Three-Mode	All	High speed	300	5.0	14.6	6.6	0.310
		Low speed		5.0	14.8	6.4	0.301
		Idle in drive		5.0	17.2	3.5	0.167
		Idle in neutral		5.0	18.4	2.8	0.130
	Automatic	High speed	229	3.4	18.0	6.0	0.251
		Low speed		4.4	17.3	6.8	0.281
		Idle in drive		7.3	19.2	4.8	0.200
		Idle in neutral		5.1	20.9	3.2	0.132
	Manual	High speed	71	10.6	4.2	7.7	0.647
		Low speed		6.0	6.0	6.0	0.496
		Idle in drive		1.0	11.9	1.0	0.006
		Idle in neutral		4.1	10.2	1.7	0.145

(a) Short Test Effectiveness $= \frac{\text{\% FF for short test}}{\text{\% FTP failures in same population}}$

Table 99. Comparison of ST Multiple Constituent Results by Transmission Type — Predicted Population, Three Cities, Bounded Errors of Commission Method (E_c Set at 5 Percent)

Short Test	Transmission Type	Test Mode	No. of Vehicles	Parameter (percent)			STE[(a)]
				E_c	E_o	FF	
Federal Short Cycle	All		300	7.0	11.7	53.7	0.821
	Automatic		229	7.0	13.1	56.8	0.813
	Manual		71	7.0	7.0	46.7	0.870
Federal Three-Mode	All	High speed	300	3.3	42.7	3.3	0.072
		Low speed		6.3	37.0	28.3	0.433
		Idle in drive		6.3	19.3	46.0	0.704
		Idle in neutral		4.7	26.3	39.0	0.597
		Best[(b)]		4.3	22.0	43.3	0.663
	Automatic	High speed	229	1.3	47.6	22.3	0.319
		Low speed		3.0	40.6	29.3	0.419
		Idle in drive		5.7	20.5	49.3	0.706
		Idle in neutral		2.6	29.7	40.2	0.575
		Best[(b)]		2.2	24.4	45.4	0.650
	Manual	High speed	71	9.9	26.8	24.0	0.472
		Low speed		17.0	25.3	25.3	0.500
		Idle in drive		8.4	15.5	35.2	0.694
		Idle in neutral		11.3	15.5	35.2	0.694
		Best[(b)]		11.3	14.1	36.6	0.722

(a) Short Test Effectiveness = $\frac{\text{\% FF for short test}}{\text{\% FTP failures in same population}}$

(b) Best mode is: HC and CO at idle in drive
NO_x at high speed

Table 100. Comparison of ST HC Results by Manufacturer — Predicted Population, Three Cities, Bounded Errors of Commission Method (E_c Set at 5 Percent)

Short Test	Manufacturer	Test Mode	No. of Vehicles	Parameter (percent)			STE[a]
				E_c	E_o	FF	
Federal Short Cycle	All		300	5.0	13.0	18.7	0.589
	General Motors		99	3.9	10.1	21.0	0.676
	Ford		61	3.8	9.0	16.2	0.642
	Chrysler		36	3.6	20.7	36.5	0.638
	American Motors		18	0.4	11.3	10.9	0.491
	Other		86	5.1	15.0	17.9	0.544
Federal Three-Mode	All	High speed	300	5.0	26.2	5.4	0.172
		Low speed		5.0	24.1	7.5	0.237
		Idle in drive		5.0	19.8	11.9	0.375
		Idle in neutral		5.0	21.0	10.7	0.338
	General Motors	High speed	99	3.1	27.1	4.0	0.129
		Low speed		2.9	24.4	6.7	0.215
		Idle in drive		4.5	15.2	15.9	0.511
		Idle in neutral		5.2	15.9	15.2	0.489
	Ford	High speed	61	4.1	22.1	3.1	0.123
		Low speed		4.1	21.3	4.0	0.157
		Idle in drive		2.3	20.3	4.9	0.195
		Idle in neutral		3.6	19.8	5.5	0.217
	Chrysler	High speed	36	2.4	40.8	5.4	0.116
		Low speed		2.0	40.2	5.9	0.129
		Idle in drive		3.7	36.4	20.8	0.364
		Idle in neutral		7.8	29.1	17.6	0.377
	American Motors	High speed	18	6.0	16.7	3.0	0.150
		Low speed		4.5	13.5	6.1	0.312
		Idle in drive		5.1	14.6	7.5	0.340
		Idle in neutral		3.9	16.3	5.8	0.263
	Other	High speed	86	8.6	23.6	9.4	0.285
		Low speed		8.9	21.6	11.3	0.343
		Idle in drive		6.1	22.5	10.5	0.318
		Idle in neutral		4.6	25.8	7.1	0.216

[a] Short Test Effectiveness = $\frac{\text{\% FF for short test}}{\text{\% FTP failures in same population}}$

Table 101. Comparison of ST CO Results by Manufacturer — Predicted Population, Three Cities, Bounded Errors of Commission Method (E_c Set at 5 Percent)

Short Test	Manufacturer	Test Mode	No. of Vehicles	Parameter (percent)			STE[a]
				E_c	E_o	FF	
Federal Short Cycle	All		300	5.0	16.7	37.1	0.690
	General Motors		99	2.4	18.2	35.8	0.663
	Ford		61	4.8	14.4	39.4	0.732
	Chrysler		36	0.2	28.1	52.5	0.652
	American Motors		18	1.2	14.7	15.3	0.510
	Other		86	14.0	8.9	33.3	0.790
Federal Three-Mode	All	High speed	300	5.0	44.4	10.6	0.193
		Low speed		5.0	40.7	14.4	0.261
		Idle in drive		5.0	24.4	31.4	0.562
		Idle in neutral		5.0	26.6	29.3	0.524
	General Motors	High speed	99	1.5	51.3	5.1	0.091
		Low speed		1.4	45.0	11.8	0.208
		Idle in drive		2.0	26.7	31.1	0.538
		Idle in neutral		2.6	28.9	28.9	0.500
	Ford	High speed	61	3.0	45.0	11.2	0.200
		Low speed		3.9	37.7	18.6	0.330
		Idle in drive		4.2	28.3	29.3	0.509
		Idle in neutral		3.1	31.7	26.0	0.451
	Chrysler	High speed	36	1.5	69.0	11.9	0.148
		Low speed		0.4	76.3	5.6	0.069
		Idle in drive		9.5	8.2	71.8	0.898
		Idle in neutral		10.1	8.4	71.7	0.896
	American Motors	High speed	18	0.4	23.7	6.3	0.210
		Low speed		0.0	41.9	0.0	0
		Idle in drive		2.5	14.2	15.7	0.525
		Idle in neutral		1.0	14.3	15.6	0.522
	Other	High speed	86	8.7	24.9	17.2	0.409
		Low speed		10.9	22.9	19.3	0.457
		Idle in drive		12.7	16.6	25.6	0.607
		Idle in neutral		12.1	20.3	21.9	0.519

[a] Short Test Effectiveness = $\frac{\%\ \text{FF for short test}}{\%\ \text{FTP failures in same population}}$

Table 102. Comparison of ST NO_x Results by Manufacturer — Predicted Population, Three Cities, Bounded Errors of Commission Method (E_c Set at 5 Percent)

Short Test	Manufacturer	Test Mode	No. of Vehicles	Parameter (percent)			STE[a]
				E_c	E_o	FF	
Federal Short Cycle	All		300	5.0	8.4	12.8	0.604
	General Motors		99	1.6	8.8	11.4	0.564
	Ford		61	3.5	16.1	13.9	0.463
	Chrysler		36	23.6	2.9	13.3	0.817
	American Motors		18	14.5	1.4	30.1	0.957
	Other		86	2.5	7.9	7.6	0.492
Federal Three-Mode	All	High speed	300	5.0	14.6	6.6	0.310
		Low speed		5.0	14.8	6.4	0.302
		Idle in drive		5.0	17.6	3.5	0.168
		Idle in neutral		5.0	18.4	2.8	0.130
	General Motors	High speed	99	4.2	15.5	4.6	0.229
		Low speed		2.8	15.3	4.9	0.243
		Idle in drive		9.6	14.9	5.2	0.259
		Idle in neutral		5.2	16.6	3.5	0.175
	Ford	High speed	61	1.4	23.7	6.3	0.210
		Low speed		0.4	28.1	2.0	0.065
		Idle in drive		4.9	28.3	1.8	0.059
		Idle in neutral		0.0	36.6	0.0	0
	Chrysler	High speed	36	7.1	10.6	5.7	0.349
		Low speed		22.4	4.0	12.3	0.755
		Idle in drive		4.8	14.9	1.4	0.085
		Idle in neutral		2.5	15.1	1.2	0.076
	American Motors	High speed	18	0.2	28.7	2.7	0.087
		Low speed		4.2	24.0	5.2	0.177
		Idle in drive		14.3	17.8	13.7	0.434
		Idle in neutral		6.2	24.0	5.3	0.181
	Other	High speed	86	7.5	7.6	6.6	0.467
		Low speed		5.4	7.9	7.6	0.489
		Idle in drive		0.7	14.6	1.0	0.062
		Idle in neutral		1.0	14.0	0.3	0.020

[a] Short Test Effectiveness = $\frac{\text{\% FF for short test}}{\text{\% FTP failures in same population}}$

Table 103. Comparison of ST Multiple Constituent Results by Manufacturer — Predicted Population, Three Cities, Bounded Errors of Commission Method (E_c Set at 5 Percent)

Short Test	Manufacturer	Test Mode	No. of Vehicles	Parameter (percent)			STE[a]
				E_c	E_o	FF	
Federal Short Cycle	All		300	7.0	11.7	53.7	0.821
	General Motors		99	2.0	8.1	57.6	0.877
	Ford		61	8.2	19.7	45.9	0.700
	Chrysler		36	8.3	22.2	63.9	0.742
	American Motors		18	16.7	5.6	61.1	0.916
	Other		86	9.3	7.0	48.8	0.875
Federal Three-Mode	All	High speed	300	3.3	42.7	22.7	0.347
		Low speed		6.3	37.0	28.3	0.433
		Idle in drive		6.3	19.3	46.0	0.704
		Idle in neutral		4.7	26.3	39.0	0.597
		Best[b]		4.3	22.0	43.3	0.663
	General Motors	High speed	99	1.0	48.5	17.2	0.262
		Low speed		1.0	41.4	24.2	0.369
		Idle in drive		7.1	13.1	52.5	0.800
		Idle in neutral		1.0	20.2	45.5	0.693
		Best[b]		1.0	20.2	45.5	0.693
	Ford	High speed	61	0.0	45.9	19.7	0.300
		Low speed		4.9	44.3	21.3	0.325
		Idle in drive		1.6	32.8	32.8	0.500
		Idle in neutral		1.6	37.7	27.9	0.425
		Best[b]		1.6	31.2	34.4	0.524
	Chrysler	High speed	36	0.0	58.3	27.8	0.323
		Low speed		0.0	41.7	44.4	0.516
		Idle in drive		5.6	19.4	66.7	0.775
		Idle in neutral		5.6	19.4	66.7	0.775
		Best[b]		5.6	19.4	66.7	0.775
	American Motors	High speed	18	0.0	50.0	16.7	0.250
		Low speed		0.0	44.4	22.2	0.408
		Idle in drive		5.6	27.8	38.9	0.583
		Idle in neutral		5.6	50.0	16.7	0.250
		Best[b]		0.0	44.4	22.2	0.408
	Other	High speed	86	10.5	25.6	30.2	0.541
		Low speed		17.4	23.3	32.6	0.583
		Idle in drive		9.3	15.1	40.7	0.729
		Idle in neutral		10.5	23.3	32.6	0.583
		Best[b]		10.5	14.0	41.9	0.749

[a] Short Test Effectiveness = $\frac{\text{\% FF for short test}}{\text{\% FTP failures in same population}}$

[b] Best mode is: HC and CO at idle in drive: NO_x at high speed

Table 104. Estimated Standard Errors for Contingency Table Percentages in Multiple Constituent Test Results

No. of Vehicles	Estimated Percentage					
	5	10	20	30 or 70	40 or 60	50
300	1.26	1.73	2.31	2.65	2.82	2.89
151	1.77	2.44	3.26	3.73	3.99	4.07
100	2.18	3.00	4.00	4.58	4.90	5.00
95	2.24	3.08	4.10	4.70	5.03	5.13
54	2.97	4.08	5.44	6.24	6.67	6.80

Table 105. Comparison of Federal Short Cycle Cut-Points by City (E_c Set at 5 Percent)

City	No. of Vehicles	ST Cut Points and Standard Errors (gm/mi)					
		HC		CO		NO_x	
		CP[a]	SE[b]	CP	SE	CP	SE
All	300	1.32	0.145	8.40	0.866	2.62	0.219
Chicago	100	1.24	0.283	7.99	1.240	2.54	0.355
Houston	100	1.24	0.181	7.49	1.327	2.56	0.360
Phoenix	100	1.44	0.267	9.48	1.916	2.77	0.412

[a] CP = cut point

[b] SE = standard error

Table 106. Comparison of Federal Three-Mode Cut-Points by City (E_c Set at 5 Percent)

City	No. of Vehicles	ST Cut-Points and Standard Errors (ppm)(a)					
		HC Idle in Drive		CO Idle in Drive		NO_x High Speed	
		CP(b)	SE(c)	CP	SE	CP	SE
All	300	184	26	7,081	1,251	2,265	243
Chicago	100	241	78	10,145	2,627	2,026	410
Houston	100	132	27	6,175	2,432	2,172(d)	393(d)
Phoenix	100	174	31	5,494	1,510	2,439	379

(a) ppm = parts per million

(b) CP = cut point

(c) SE = standard error

(d) The best mode for NO_x for Houston was found to be the low speed mode. The cut point and standard error for NO_x low speed are 1500 ppm and 372 ppm, respectively

Table 107. Comparison of HC Results for CID[a] = 150 and Less, by Manufacturer – Predicted Population, Three Cities, Bounded Errors of Commission Method (E_c Set at 5 Percent)

Short Test	Manufacturer	Test Mode	No. of Vehicles	Parameter (percent)			STE[b]
				E_c	E_o	FF	
Federal Short Cycle	All		95	5.0	13.0	19.1	0.595
	General Motors		12	2.9	13.4	20.5	0.605
	Ford		6	2.1	5.4	13.9	0.720
	Chrysler						
	American Motors						
	Datsun		8	3.9	6.7	41.7	0.862
	Toyota		9	0.3	31.5	11.8	0.273
	VW, Porsche, Audi		21	2.7	18.9	17.7	0.484
	Honda		6	4.9	7.4	0.8	0.098
	Others		33	7.2	10.3	19.4	0.653
Federal Three-Mode	All	High speed	95	5.0	25.9	6.2	0.193
		Low speed		5.0	24.0	8.1	0.252
		Idle in drive		5.0	21.9	10.2	0.318
		Idle in neutral		5.0	23.4	8.7	0.271
	General Motors	High speed	12	0.65	31.8	2.1	0.062
		Low speed		0.30	30.6	3.3	0.097
		Idle in drive		11.3	14.4	19.5	0.575
		Idle in neutral		10.2	13.6	20.3	0.599
	Ford	High speed	6	0.8	19.2	0.1	0.005
		Low speed		1.2	19.2	0.1	0.005
		Idle in drive		3.3	13.3	6.0	0.311
		Idle in neutral		5.2	12.5	6.7	0.349
	Datsun	High speed	8	10.7	22.3	26.1	0.539
		Low speed		10.6	19.0	29.4	0.607
		Idle in drive		5.4	30.3	18.1	0.374
		Idle in neutral		0.9	44.9	3.6	0.074
	Toyota	High speed	9	2.6	33.5	9.9	0.228
		Low speed		4.0	15.9	27.5	0.633
		Idle in drive		2.8	37.8	5.5	0.127
		Idle in neutral		1.5	40.2	3.1	0.072
	VW, Porsche, Audi	High speed	21	8.1	24.6	12.0	0.328
		Low speed		5.8	21.9	14.6	0.400
		Idle in drive		4.2	23.4	13.1	0.359
		Idle in neutral		4.6	22.3	14.2	0.389
	Honda	High speed	6	0.0	8.2	0.0	0
		Low speed		0.07	8.2	0.02	0.002
		Idle in drive		2.9	2.6	5.6	0.683
		Idle in neutral		5.6	1.5	6.6	0.815
	Others	High speed	33	5.4	25.6	4.1	0.138
		Low speed		4.5	25.6	4.1	0.138
		Idle in drive		4.2	21.9	7.8	0.263
		Idle in neutral		3.7	25.1	4.7	0.158

[a] CID = cubic inch displacement

[b] Short Test Effectiveness = $\frac{\%\ \text{FF for short test}}{\%\ \text{FTP failures in same population}}$

Table 108. Comparison of CO Results for CID[a] = 150 and Less, by Manufacturer — Predicted Population, Three Cities, Bounded Errors of Commission Method (E_c Set at 5 Percent)

				Parameter (percent)			
Short Test	**Manufacturer**	**Test Mode**	**No. of Vehicles**	E_c	E_o	**FF**	**STE[b]**
Federal Short Cycle	All		95	5.0	19.4	25.4	0.567
	General Motors		12	0.1	36.9	40.5	0.523
	Ford		6	0.0	23.8	1.8	0.070
	Chrysler						
	American Motors						
	Datsun		8	0.4	33.1	19.8	0.374
	Toyota		9	3.7	25.6	8.6	0.251
	VW, Audi, Porsche		21	4.9	24.5	23.4	0.489
	Honda		6	0.0	0.0	0.0	--
	Others		33	6.8	10.7	30.8	0.742
Federal Three-Mode	All	High speed	95	5.0	38.0	6.7	0.150
		Low speed		5.0	34.7	10.0	0.224
		Idle in drive		5.0	26.4	18.4	0.411
		Idle in neutral		5.0	28.8	16.0	0.357
	General Motors	High speed	12	0.8	75.1	2.3	0.030
		Low speed		0.05	68.4	9.0	0.116
		Idle in drive		6.7	15.4	64.1	0.806
		Idle in neutral		6.6	15.7	63.8	0.803
	Ford	High speed	6	0.0	25.6	0.0	0
		Low speed		0.0	25.6	0.0	0
		Idle in drive		0.1	25.6	0.05	0.002
		Idle in neutral		0.06	25.6	0.03	0.001
	Datsun	High speed	8	0.0	40.9	6.0	0.128
		Low speed		0.0	32.3	14.6	0.311
		Idle in drive		10.9	14.7	38.2	0.722
		Idle in neutral		4.0	39.5	13.3	0.252
	Toyota	High speed	9	0.03	34.2	0.01	0
		Low speed		7.1	32.5	1.7	0.050
		Idle in drive		4.7	21.6	12.6	0.368
		Idle in neutral		3.9	29.0	5.2	0.152
	VW, Audi, Porsche	High speed	21	5.1	30.7	17.2	0.359
		Low speed		5.6	33.5	14.4	0.301
		Idle in drive		8.4	30.0	18.3	0.379
		Idle in neutral		8.9	31.6	16.7	0.346
	Honda	High speed	6	0.0	0.0	0.0	--
		Low speed		1.3	0.0	0.0	--
		Idle in drive		0.0	0.0	0.0	--
		Idle in neutral		0.0	0.0	0.0	--
	Others	High speed	33	2.5	32.6	8.9	0.215
		Low speed		4.6	29.7	11.8	0.284
		Idle in drive		2.8	26.5	15.0	0.361
		Idle in neutral		2.9	30.0	11.5	0.277

[a] CID = cubic inch displacement

[b] Short Test Effectiveness = $\frac{\%\ \text{FF for short test}}{\%\ \text{FTP failures in same population}}$

Table 109. Comparison of NO_x Results for CID[a] = 150 and Less, by Manufacturer — Predicted Population, Three Cities, Bounded Errors of Commission Method (E_c Set at 5 Percent)

Short Test	Manufacturer	Test Mode	No. of Vehicles	Parameter (percent)			STE[b]
				E_c	E_o	FF	
Federal Short Cycle	All		95	5.0	5.8	9.8	0.628
	General Motors		12	3.9	2.2	8.8	0.800
	Ford		6	19.2	5.8	7.1	0.550
	Chrysler						
	American Motors						
	Datsun		8	2.9	10.8	14.7	0.577
	Toyota		9	0.7	35.9	28.6	0.443
	VW, Audi, Porsche		21	1.2	1.1	0.2	0.154
	Honda		6	0.0	0.1	0.0	0
	Others		33	1.7	3.8	8.8	0.698
Federal Three-Mode	All	High speed	95	5.0	9.0	6.5	0.419
		Low speed		5.0	9.0	5.2	0.366
		Idle in drive		5.0	12.6	2.9	0.187
		Idle in neutral		5.0	13.2	1.0	0.070
	General Motors	High speed	12	9.9	2.7	8.3	0.755
		Low speed		11.0	5.9	5.2	0.468
		Idle in drive		18.0	10.3	0.7	0.064
		Idle in neutral		4.7	10.7	0.31	0.028
	Ford	High speed	6	0.8	12.5	0.4	0.031
		Low speed		0.01	12.9	0.04	0.003
		Idle in drive		1.3	11.2	1.7	0.132
		Idle in neutral		0.07	12.5	0.01	0
	Datsun	High speed	8	27.2	23.8	2.8	0.105
		Low speed		0.9	21.0	4.4	0.173
		Idle in drive		0.0	26.7	0.0	0
		Idle in neutral		0.01	26.7	0.0	0
	Toyota	High speed	9	0.34	57.0	6.6	0.104
		Low speed		3.8	21.7	37.7	0.635
		Idle in drive		1.0	52.6	6.7	0.113
		Idle in neutral		0.8	58.2	1.1	0.019
	VW, Audi, Porsche	High speed	21	0.6	0.9	0.4	0.308
		Low speed		10.5	0.3	0.9	0.750
		Idle in drive		5.3	0.8	0.4	0.333
		Idle in neutral		25.7	0.6	0.6	0.500
	Honda	High speed	6	0.7	0.1	0.03	0.231
		Low speed		0.8	0.01	0.0	0
		Idle in drive		0.06	0.1	0.0	0
		Idle in neutral		10.5	0.1	0.0	0
	Others	High speed	33	2.4	9.8	2.8	0.222
		Low speed		2.4	8.6	4.0	0.318
		Idle in drive		2.0	10.4	2.2	0.175
		Idle in neutral		0.2	11.9	0.2	0.017

(a) CID = cubic inch displacement

(b) Short Test Effectiveness = $\frac{\text{\% FF for short test}}{\text{\% FTP failures in same population}}$

Table 110. Comparison of Multiple Constituent Results for CID[a] = 150 and Less, by Manufacturer – Predicted Population, Three Cities, Bounded Errors of Commission Method (E_c Set at 5 Percent)

Short Test	Manufacturer	Test Mode	No. of Vehicles	Parameter (percent)			STE[b]
				E_c	E_o	FF	
Federal Short Cycle	All		95	1.1	13.7	44.2	0.763
	General Motors		12	0.0	25.0	50.0	0.667
	Ford		6	0.0	33.3	33.3	0.500
	Chrysler						
	American Motors						
	Datsun		8	12.5	0.0	62.5	1.00
	Toyota		9	0.0	22.2	55.6	0.715
	VW, Audi, Porsche		21	0.0	9.5	38.1	0.800
	Honda		6	0.0	16.7	0.0	0
	Others		33	0.0	9.1	48.5	0.842
Federal Three-Mode	All	High speed	95	6.3	38.9	18.9	0.327
		Low speed		8.4	36.8	21.0	0.363
		Idle in drive		6.3	27.4	30.5	0.527
		Idle in neutral		5.3	35.8	22.1	0.382
		Best[c]		5.3	28.4	29.5	0.509
	General Motors	High speed	12	8.3	50.0	25.0	0.333
		Low speed		8.3	58.3	16.7	0.223
		Idle in drive		8.3	0.0	75.0	1.00
		Idle in neutral		0.0	16.7	58.3	0.777
		Best[c]		8.3	16.7	58.3	0.777
	Ford	High speed	6	0.0	66.7	0.0	0
		Low speed		0.0	66.7	0.0	0
		Idle in drive		0.0	50.0	16.7	0.250
		Idle in neutral		0.0	50.0	16.7	0.250
		Best[c]		0.0	50.0	16.7	0.250
	Datsun	High speed	8	25.0	37.5	25.0	0.400
		Low speed		12.5	37.5	25.0	0.400
		Idle in drive		12.5	37.5	25.0	0.400
		Idle in neutral		12.5	50.0	12.5	0.200
		Best[c]		12.5	25.0	37.5	0.600
	Toyota	High speed	9	0.0	55.6	0.0	0
		Low speed		0.0	33.3	44.4	0.571
		Idle in drive		0.0	55.6	22.2	0.285
		Idle in neutral		0.0	55.6	22.2	0.285
		Best[c]		0.0	55.6	22.2	0.285
	VW, Audi, Porsche	High speed	21	9.5	33.3	14.3	0.300
		Low speed		19.0	19.0	28.6	0.601
		Idle in drive		14.3	14.3	33.3	0.700
		Idle in neutral		14.3	14.3	33.3	0.700
		Best[c]		9.5	14.3	33.3	0.700
	Honda	High speed	6	0.0	16.7	0.0	0
		Low speed		0.0	16.7	0.0	0
		Idle in drive		0.0	0.0	16.7	1.00
		Idle in neutral		0.0	0.0	16.7	1.00
		Best[c]		0.0	0.0	16.7	1.00
	Others	High speed	33	3.0	33.3	24.2	0.421
		Low speed		6.1	39.4	6.1	0.134
		Idle in drive		3.0	36.4	21.2	0.368
		Idle in neutral		3.0	51.5	6.1	0.106
		Best[c]		3.0	36.4	21.2	0.368

[a] CID = cubic inch displacement

[b] Short Test Effectiveness = $\frac{\text{\% FF for short test}}{\text{\% FTP failures in same population}}$

[c] Best mode is: HC and CO at idle in drive; NO_x at high speed

Table 111. Comparison of HC Results for CID[a] = 151 to 259, by Manufacturer — Predicted Population, Three Cities, Bounded Errors of Commission Method (E_c Set at 5 Percent)

Short Test	Manufacturer	Test Mode	No. of Vehicles	Parameter (percent)			STE[b]
				E_c	E_o	FF	
Federal Short Cycle	All		54	5.0	14.0	13.3	0.487
	General Motors		13	1.8	13.1	18.6	0.587
	Ford		13	6.0	5.3	10.8	0.671
	Chrysler		7	1.5	14.5	4.6	0.241
	American Motors		12	1.9	16.9	21.0	0.554
	Others		7	4.9	0.7	9.1	0.576
	Others[c]		9	3.6	21.1	12.0	0.363
Federal Three-Mode	All	High speed	54	5.0	23.6	3.7	0.136
		Low speed		5.0	21.3	6.0	0.220
		Idle in drive		5.0	18.8	8.4	0.309
		Idle in neutral		5.0	20.0	7.2	0.265
	General Motors	High speed	13	3.0	30.3	1.4	0.045
		Low speed		3.9	22.7	9.0	0.284
		Idle in drive		6.5	9.4	22.3	0.703
		Idle in neutral		8.4	14.4	17.3	0.546
	Ford	High speed	13	6.9	12.3	3.8	0.236
		Low speed		6.4	11.6	4.5	0.280
		Idle in drive		1.0	15.1	1.0	0.062
		Idle in neutral		0.44	15.5	1.0	0.061
	Chrysler	High speed	7	0.03	18.3	1.0	0.052
		Low speed		0.0	19.2	0.02	0.001
		Idle in drive		6.8	5.6	13.5	0.707
		Idle in neutral		3.2	7.7	11.6	0.601
	American Motors	High speed	12	15.0	28.0	9.8	0.259
		Low speed		3.0	32.5	5.4	0.143
		Idle in drive		5.3	27.3	5.6	0.170
		Idle in neutral		4.1	28.2	4.7	0.143
	Others	High speed	7	6.2	9.2	0.6	0.061
		Low speed		16.0	6.2	3.7	0.374
		Idle in drive		3.1	8.3	1.5	0.153
		Idle in neutral		3.1	9.2	0.7	0.071
	Others[c]	High speed	9	6.6	26.6	6.5	0.196
		Low speed		10.3	24.2	8.8	0.267
		Idle in drive		1.7	31.1	2.0	0.060
		Idle in neutral		1.7	31.5	1.6	0.048

(a) CID = cubic inch displacement

(b) Short Test Effectiveness $= \dfrac{\text{\% FF for short test}}{\text{\% FTP failures in same population}}$

(c) Includes one Datsun, one VW

Table 112. Comparison of CO Results for CID[a] = 151 to 259, by Manufacturer – Predicted Population, Three Cities, Bounded Errors of Commission Method (E_c Set at 5 Percent)

Short Test	Manufacturer	Test Mode	No. of Vehicles	Parameter (percent)			STE[b]
				E_c	E_o	FF	
Federal Short Cycle	All		54	5.0	14.6	41.0	0.737
	General Motors		13	0.5	20.4	44.1	0.684
	Ford		13	8.7	6.4	38.6	0.858
	Chrysler		7	2.6	30.8	38.3	0.554
	American Motors		12	4.1	16.4	34.5	0.678
	Others		7	4.6	5.6	48.4	0.896
	Others[c]		9	5.5	7.8	47.9	0.860
Federal Three-Mode	All	High speed	54	5.0	51.9	6.5	0.111
		Low speed		5.0	45.0	14.0	0.237
		Idle in drive		5.0	24.6	34.8	0.586
		Idle in neutral		5.0	32.3	27.1	0.456
	General Motors	High speed	13	0.04	64.5	0.0	0
		Low speed		1.0	59.4	7.4	0.111
		Idle in drive		7.4	14.1	50.4	0.781
		Idle in neutral		9.0	30.8	33.6	0.522
	Ford	High speed	13	6.2	36.9	16.4	0.308
		Low speed		6.1	35.5	17.7	0.333
		Idle in drive		1.5	36.2	20.4	0.360
		Idle in neutral		1.7	41.1	15.5	0.274
	Chrysler	High speed	7	0.07	67.7	0.38	0.006
		Low speed		0.27	66.3	1.7	0.025
		Idle in drive		15.3	13.6	55.5	0.803
		Idle in neutral		12.3	3.1	68.5	0.957
	American Motors	High speed	12	1.8	44.6	6.2	0.122
		Low speed		0.07	50.8	0.12	0.002
		Idle in drive		5.3	26.1	24.8	0.487
		Idle in neutral		1.1	30.3	20.6	0.405
	Others	High speed	7	1.4	44.2	9.8	0.181
		Low speed		0.7	19.3	34.7	0.643
		Idle in drive		0.8	24.5	29.5	0.546
		Idle in neutral		0.03	35.5	18.4	0.341
	Others[c]	High speed	9	2.0	43.9	11.8	0.212
		Low speed		2.6	20.2	35.5	0.637
		Idle in drive		1.0	25.0	30.7	0.551
		Idle in neutral		0.1	35.0	20.7	0.372

[a] CID = cubic inch displacement

[b] Short Test Effectiveness = $\frac{\text{\% FF for short test}}{\text{\%FTP failures in same population}}$

[c] Includes one Datsun, one VW

Table 113. Comparison of NO_x Results for CID[a] = 151 to 259, by Manufacturer — Predicted Population, Three Cities, Bounded Errors of Commission Method (E_c Set at 5 Percent)

Short Test	Manufacturer	Test Mode	No. of Vehicles	Parameter (percent)			STE[b]
				E_c	E_o	FF	
Federal Short Cycle	All		54	5.0	7.5	12.5	0.625
	General Motors		13	0.5	10.8	11.0	0.505
	Ford		13	6.2	8.4	4.7	0.359
	Chrysler		7	5.0	6.9	27.4	0.799
	American Motors		12	13.6	1.7	26.0	0.939
	Others		7	0.6	7.5	3.0	0.286
	Others[c]		9	0.6	7.6	3.9	0.339
Federal Three-Mode	All	High speed	54	5.0	15.4	4.6	0.230
		Low speed		5.0	11.1	8.9	0.445
		Idle in drive		5.0	16.7	3.3	0.165
		Idle in neutral		5.0	17.5	2.5	0.125
	General Motors	High speed	13	5.8	20.1	1.8	0.082
		Low speed		8.4	7.7	14.2	0.648
		Idle in drive		9.8	16.7	5.1	0.234
		Idle in neutral		13.1	15.7	6.7	0.299
	Ford	High speed	13	2.9	9.0	4.1	0.313
		Low speed		1.5	9.9	3.2	0.244
		Idle in drive		0.03	10.9	0.0	0
		Idle in neutral		0.0	10.9	0.0	0
	Chrysler	High speed	7	7.4	20.7	13.5	0.395
		Low speed		7.0	6.2	28.0	0.819
		Idle in drive		0.12	34.0	0.2	0.006
		Idle in neutral		0.3	33.4	1.0	0.029
	American Motors	High speed	12	2.0	20.0	7.7	0.278
		Low speed		5.2	17.6	8.2	0.318
		Idle in drive		6.2	20.1	7.5	0.272
		Idle in neutral		0.8	26.7	0.9	0.033
	Others	High speed	7	2.0	9.0	1.5	0.143
		Low speed		0.4	10.1	0.4	0.038
		Idle in drive		0.1	9.9	0.6	0.057
		Idle in neutral		0.0	10.5	0.0	0
	Others[c]	High speed	9	4.8	7.8	3.7	0.322
		Low speed		1.3	10.1	1.4	0.122
		Idle in drive		0.04	11.3	0.2	0.017
		Idle in neutral		0.0	11.5	0.0	0

[a] CID = cubic inch displacement

[b] Short Test Effectiveness = $\frac{\%\ \text{FF for short test}}{\%\ \text{FTP failures in same population}}$

[c] Includes one Datsun, one VW

Table 114. Comparison of Multiple Constituents Results for CID[a] = 151 259, by Manufacturer — Predicted Population, Three Cities, Bounded Errors of Commission Method (E_c Set at 5 Percent)

Short Test	Manufacturer	Test Mode	No. of Vehicles	Parameter (percent)			STE[b]
				E_c	E_o	FF	
Federal Short Cycle	All		54	5.6	13.0	55.6	0.812
	General Motors		13	0.0	15.4	53.9	0.779
	Ford		13	0.0	0.0	46.2	1.00
	Chrysler		7	0.0	57.1	28.6	0.334
	American Motors		12	8.3	8.3	75.0	0.900
	Others		7	28.6	0.0	71.43	1.00
	Others[c]		9	22.2	0.0	66.7	1.00
Federal Three-Mode	All	High speed	54	1.8	55.6	13.0	0.190
		Low speed		3.7	35.2	33.3	0.486
		Idle in drive		5.6	20.1	44.4	0.648
		Idle in neutral		3.7	35.2	33.3	0.486
		Best[d]		1.8	22.2	46.3	0.676
	General Motors	High speed	13	0.0	61.5	7.7	0.111
		Low speed		0.0	23.1	46.1	0.666
		Idle in drive		15.4	0.0	69.2	1.00
		Idle in neutral		13.1	15.7	6.2	0.283
		Best[d]		7.7	15.4	53.8	0.777
	Ford	High speed	13	0.0	30.8	15.4	0.333
		Low speed		7.7	15.4	30.8	0.667
		Idle in drive		0.0	30.8	15.4	0.333
		Idle in neutral		0.0	30.8	15.4	0.333
		Best[d]		0.0	23.1	23.1	0.500
	Chrysler	High speed	7	0.0	71.4	14.3	0.167
		Low speed		0.0	57.1	28.6	0.334
		Idle in drive		14.3	14.3	71.4	0.833
		Idle in neutral		14.3	14.3	71.4	0.833
		Best[d]		14.3	14.3	71.4	0.833
	American Motors	High speed	12	0.0	58.3	25.0	0.300
		Low speed		0.0	58.3	25.0	0.300
		Idle in drive		0.0	41.7	41.7	0.500
		Idle in neutral		0.0	66.7	16.7	0.200
		Best[d]		0.0	41.7	41.7	0.500
	Others	High speed	7	0.0	71.4	0.0	0
		Low speed		0.0	42.9	28.6	0.400
		Idle in drive		0.0	42.9	28.6	0.400
		Idle in neutral		0.0	57.1	14.3	0.200
		Best[d]		0.0	42.9	28.6	0.400
	Others[c]	High speed	9	11.1	66.7	0.0	0
		Low speed		11.1	33.3	33.3	0.500
		Idle in drive		0.0	33.3	33.3	0.500
		Idle in neutral		0.0	44.4	22.2	0.333
		Best[d]		0.0	33.3	33.3	0.500

[a] CID = cubic inch displacement

[b] Short Test Effectiveness = $\dfrac{\text{\% FF for short test}}{\text{\% FTP failures in same population}}$

[c] Includes one Datsun, one VW

[d] Best mode is: HC and CO at idle in drive; NO_x at high speed

Table 115. Comparison of HC Results for CID[a] = 260 and Greater, by Manufacturer — Predicted Population, Three Cities, Bounded Errors of Commission Method (E_c Set at 5 Percent)

Short Test	Manufacturer	Test Mode	No. of Vehicles	Parameter (percent)			STE[b]
				E_c	E_o	FF	
Federal Short Cycle	All		151	5.0	12.5	20.4	0.620
	General Motors		74	4.0	8.9	21.8	0.710
	Ford		42	2.8	11.4	18.0	0.612
	Chrysler		29	4.0	20.3	40.5	0.666
	American Motors		6	0.0	0.0	0.0	--
Federal Three-Mode	All	High speed	151	5.0	27.0	5.6	0.172
		Low speed		5.0	24.7	8.0	0.245
		Idle in drive		5.0	18.3	14.6	0.444
		Idle in neutral		5.0	19.6	13.3	0.404
	General Motors	High speed	74	4.8	24.7	6.0	0.195
		Low speed		4.7	22.1	8.6	0.280
		Idle in drive		4.0	14.4	16.3	0.531
		Idle in neutral		4.2	15.9	14.8	0.482
	Ford	High speed	42	5.1	26.0	3.4	0.116
		Low speed		5.2	23.8	5.7	0.193
		Idle in drive		3.9	20.6	8.8	0.299
		Idle in neutral		5.1	21.2	8.3	0.281
	Chrysler	High speed	29	4.2	41.8	8.7	0.172
		Low speed		4.3	39.7	10.8	0.214
		Idle in drive		5.9	29.2	31.6	0.520
		Idle in neutral		6.2	31.1	29.7	0.488
	American Motors	High speed	6	0.0	0.0	0.0	--
		Low speed		0.0	0.0	0.0	--
		Idle in drive		0.0	0.0	0.0	--
		Idle in neutral		0.0	0.0	0.0	--

[a] CID = cubic inch displacement

[b] Short Test Effectiveness = $\frac{\text{\% FF for short test}}{\text{\% FTP failures in same population}}$

Table 116. Comparison of CO Results for CID[a] = 260 and Greater, by Manufacturer – Predicted Population, Three Cities, Bounded Errors of Commission Method (E_c Set at 5 Percent)

Short Test	Manufacturer	Test Mode	No. of Vehicles	Parameter (percent)			STE[b]
				E_c	E_o	FF	
Federal Short Cycle	All		151	5.0	13.0	44.2	0.773
	General Motors		74	5.2	12.2	38.1	0.758
	Ford		42	10.1	8.4	52.0	0.861
	Chrysler		29	2.0	6.6	76.4	0.920
	American Motors		6	0.4	0.0	0.0	--
Federal Three-Mode	All	High speed	151	5.0	41.4	17.4	0.296
		Low speed		5.0	38.0	21.9	0.366
		Idle in drive		5.0	17.8	42.1	0.703
		Idle in neutral		5.0	18.8	41.3	0.687
	General Motors	High speed	74	3.4	40.7	12.3	0.232
		Low speed		3.6	34.7	18.5	0.348
		Idle in drive		3.0	20.1	34.4	0.631
		Idle in neutral		3.5	21.2	33.3	0.611
	Ford	High speed	42	7.7	35.2	25.1	0.416
		Low speed		8.6	22.9	37.5	0.621
		Idle in drive		13.0	9.4	52.1	0.847
		Idle in neutral		10.2	11.6	49.8	0.811
	Chrysler	High speed	29	3.8	58.6	24.6	0.296
		Low speed		1.4	70.2	14.4	0.170
		Idle in drive		8.6	5.2	77.8	0.937
		Idle in neutral		8.9	5.5	77.4	0.934
	American Motors	High speed	6	0.0	0.06	0.0	--
		Low speed		0.2	0.0	0.0	--
		Idle in drive		0.2	0.0	0.0	--
		Idle in neutral		0.4	0.0	0.0	--

[a] CID = cubic inch displacement

[b] Short Test Effectiveness = $\frac{\text{\% FF for short test}}{\text{\% FTP failures in same population}}$

Table 117. Comparison of NO_x Results for CID[a] = 260 and Greater, by Manufacturer – Predicted Population, Three Cities, Bounded Errors of Commission Method (E_c Set at 5 Percent)

Short Test	Manufacturer	Test Mode	No. of Vehicles	Parameter (percent)			STE[b]
				E_c	E_o	FF	
Federal Short Cycle	All		151	5.0	11.5	13.3	0.536
	General Motors		74	1.1	10.9	10.7	0.495
	Ford		42	0.6	23.5	14.7	0.385
	Chrysler		29	20.9	2.1	10.0	0.827
	American Motors		6	9.0	2.4	38.9	0.942
Federal Three-Mode	All	High speed	151	5.0	16.3	8.5	0.343
		Low speed		5.0	19.4	5.4	0.218
		Idle in drive		5.0	21.5	3.2	0.130
		Idle in neutral		5.0	20.8	4.0	0.161
	General Motors	High speed	74	4.0	15.3	6.2	0.288
		Low speed		1.0	17.6	3.9	0.181
		Idle in drive		6.5	16.3	5.3	0.245
		Idle in neutral		4.3	17.2	4.3	0.200
	Ford	High speed	42	3.0	25.4	12.8	0.335
		Low speed		0.2	35.4	2.8	0.073
		Idle in drive		0.01	45.3	0.0	0
		Idle in neutral		0.2	45.0	0.2	0.004
	Chrysler	High speed	29	12.2	6.3	5.8	0.479
		Low speed		28.2	2.1	10.0	0.826
		Idle in drive		4.0	11.4	0.7	0.058
		Idle in neutral		4.7	10.8	1.3	0.107
	American Motors	High speed	6	0.0	34.9	3.3	0.086
		Low speed		2.8	33.4	4.8	0.126
		Idle in drive		0.6	30.6	7.6	0.199
		Idle in neutral		0.1	38.6	2.7	0.065

[a] CID = cubic inch displacement

[b] Short Test Effectiveness = $\frac{\text{\% FF for short test}}{\text{\% FTP failures in same population}}$

Table 118. Comparison of Multiple Constituent Results for CID[a] = 260 or Greater, by Manufacturer — Predicted Population, Three Cities, Bounded Errors of Commission Method (E_c Set at 5 Percent)

Short Test	Manufacturer	Test Mode	No. of Vehicles	Parameter (percent)			STE[b]
				E_c	E_o	FF	
Federal Short Cycle	All		151	8.0	6.6	62.3	0.904
	General Motors		74	4.1	4.1	59.5	0.937
	Ford		42	14.3	7.1	64.3	0.901
	Chrysler		29	3.5	13.8	72.4	0.840
	American Motors		6	33.3	0.0	33.3	1.00
Federal Three-Mode	All	High speed	151	2.6	24.5	10.0	0.290
		Low speed		2.6	33.8	2.6	0.071
		Idle in drive		6.0	19.2	49.7	0.721
		Idle in neutral		5.3	17.9	51.0	0.740
		Best[c]		4.0	19.9	49.0	0.711
	General Motors	High speed	74	0.0	43.2	20.3	0.320
		Low speed		1.3	39.2	24.3	0.383
		Idle in drive		4.0	17.6	46.0	0.723
		Idle in neutral		1.3	17.6	46.0	0.723
		Best[c]		0.0	23.0	40.5	0.638
	Ford	High speed	42	7.1	35.7	35.7	0.500
		Low speed		7.1	23.8	47.6	0.667
		Idle in drive		11.9	19.0	52.4	0.734
		Idle in neutral		14.3	16.7	54.8	0.766
		Best[c]		11.9	16.7	54.8	0.766
	Chrysler	High speed	29	0.0	31.0	55.2	0.640
		Low speed		0.0	34.5	51.7	0.600
		Idle in drive		3.4	20.7	65.5	0.760
		Idle in neutral		3.4	17.2	69.0	0.800
		Best[c]		3.4	13.8	72.4	0.840
	American Motors	High speed	6	0.0	33.3	0.0	0
		Low speed		0.0	33.3	0.0	0
		Idle in drive		0.0	33.3	0.0	0
		Idle in neutral		0.0	33.3	0.0	0
		Best[c]		0.0	33.3	0.0	0

[a] CID = cubic inch displacement

[b] Short Test Effectiveness = $\frac{\%\ \text{FF for short test}}{\%\ \text{FTP failures in same population}}$

[c] Best mode is: HC and CO at idle in drive; NO_x at high speed

Table 119. Comparison of Federal Short Cycle Cut-Points by Engine Displacement (E_c Set at 5 Percent)

Engine Displacement Group	No. of Vehicles	ST Cut-Points and Standard Errors (gm/mi)					
		HC		CO		NO_x	
		CP[a]	SE[b]	CP	SE	CP	SE
All	300	1.32	0.145	8.40	0.866	2.62	0.219
150 CID and Less	95	1.28	0.234	13.10	1.920	2.37	0.439
151 to 259 CID	54	1.27	0.464	6.24	1.124	2.62	0.440
260 CID and Greater	151	1.35	0.192	5.61	0.821	2.78	0.285

[a] CP = cut point

[b] SE = standard error

Table 120. Comparison of Federal Three-Mode Cut-Points by Engine Displacement[a] (E_c Set at 5 Percent)

Engine Displacement Group	No. of Vehicles	ST Cut-Points and Standard Errors (ppm)					
		HC[b]		CO[b]		NO_x[c]	
		CP[d]	SE[e]	CP	SE	CP	SE
All Three Cities	300	184	26	7,081	1,251	2,265	243
150 CID and Less	95	219	57	18,382	5,863	2,805	665
151 to 259 CID	54	213	79	7,063	2,488	1,985[f]	446[f]
260 CID and Greater	151	151	26	2,655	607	1,986	252

[a] Engine cubic inch displacement = CID

[b] Tested at idle in drive

[c] Tested at high speed

[d] CP = cut point

[e] SE = standard error

[f] Best NO_x mode is at low speed. CP and SE for the low speed NO_x are 1396 ppm and 423 ppm, respectively

Table 121. Comparison of HC Results for CID[a] = 150 and Less, by City – Predicted Population, Three Cities, Bounded Errors of Commission Method (E_c Set at 5 Percent)

Short Test	City	Test Mode	No. of Vehicles	Parameter (percent)			STE[b]
				E_c	E_o	FF	
Federal Short Cycle	All		95	5.0	13.0	19.1	0.595
	Chicago		32	4.8	15.7	16.3	0.509
	Houston		33	4.4	12.9	27.0	0.677
	Phoenix		30	5.3	8.6	14.1	0.621
Federal Three-Mode	All	High speed	95	5.0	25.9	6.2	0.193
		Low speed		5.0	24.1	8.1	0.252
		Idle in drive		5.0	22.0	10.2	0.317
		Idle in neutral		5.0	23.5	8.7	0.270
	Chicago	High speed	32	9.9	20.7	11.4	0.355
		Low speed		6.8	18.9	13.1	0.409
		Idle in drive		9.5	18.1	13.9	0.434
		Idle in neutral		10.0	19.6	12.5	0.389
	Houston	High speed	33	1.2	35.9	4.0	0.100
		Low speed		1.7	32.5	7.4	0.185
		Idle in drive		2.0	26.7	13.2	0.331
		Idle in neutral		2.4	29.0	10.8	0.271
	Phoenix	High speed	30	4.7	19.3	3.3	0.146
		Low speed		6.3	18.0	4.6	0.204
		Idle in drive		3.1	19.2	3.4	0.150
		Idle in neutral		2.4	20.1	2.5	0.111

[a] CID = cubic inch displacement

[b] Short Test Effectiveness = $\frac{\text{\% FF for short test}}{\text{\% FTP failures in same population}}$

Table 122. Comparison of CO Results for CID[a] = 150 and Less, by City — Predicted Population, Three Cities, Bounded Errors of Commission Method (E_c Set at 5 Percent)

Short Test	City	Test Mode	No. of Vehicles	Parameter (percent)			STE[b]
				E_c	E_o	FF	
Federal Short Cycle	All		95	5.0	19.4	25.4	0.567
	Chicago		32	3.0	27.7	23.8	0.462
	Houston		33	4.7	20.6	30.1	0.594
	Phoenix		30	7.2	13.3	20.3	0.604
Federal Three-Mode	All	High speed	95	5.0	38.0	6.7	0.150
		Low speed		5.0	34.7	10.0	0.224
		Idle in drive		5.0	26.4	18.4	0.411
		Idle in neutral		5.0	28.8	16.0	0.357
	Chicago	High speed	32	5.0	41.7	9.9	0.192
		Low speed		7.3	40.0	11.5	0.223
		Idle in drive		7.7	29.4	22.2	0.430
		Idle in neutral		6.1	31.1	20.5	0.397
	Houston	High speed	33	5.4	44.7	6.0	0.118
		Low speed		4.7	38.3	12.4	0.245
		Idle in drive		5.4	31.0	20.0	0.392
		Idle in neutral		6.6	33.8	17.2	0.337
	Phoenix	High speed	30	3.1	29.1	4.5	0.134
		Low speed		2.5	29.1	4.5	0.134
		Idle in drive		2.7	21.0	12.6	0.375
		Idle in neutral		2.4	23.7	9.9	0.295

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[a] CID = cubic inch displacement

[b] Short Test Effectiveness = $\frac{\text{\% FF for short test}}{\text{\% FTP failures in same population}}$

Table 123. Comparison of NO_x Results for CID[(a)] = 150 and Less, by City — Predicted Population, Three Cities, Bounded Errors of Commission Method (E_c Set at 5 Percent)

Short Test	City	Test Mode	No. of Vehicles	Parameter (percent)			STE[(b)]
				E_c	E_o	FF	
Federal Short Cycle	All		95	5.0	5.8	9.8	0.628
	Chicago		32	2.9	5.0	12.3	0.711
	Houston		33	3.6	5.5	10.5	0.656
	Phoenix		30	7.4	5.9	7.5	0.559
Federal Three-Mode	All	High speed	95	5.0	9.0	6.5	0.419
		Low speed		5.0	9.0	5.2	0.366
		Idle in drive		5.0	12.6	2.9	0.187
		Idle in neutral		5.0	13.2	1.0	0.070
	Chicago	High speed	32	0.7	15.8	0.8	0.048
		Low speed		0.9	15.4	1.1	0.067
		Idle in drive		0.1	16.5	0.03	0.002
		Idle in neutral		2.1	15.9	0.7	0.042
	Houston	High speed	33	3.8	8.8	7.1	0.447
		Low speed		5.0	7.9	5.2	0.397
		Idle in drive		3.0	9.7	6.2	0.390
		Idle in neutral		1.3	12.0	1.0	0.077
	Phoenix	High speed	30	4.6	4.8	8.8	0.647
		Low speed		7.7	2.8	10.6	0.791
		Idle in drive		8.4	11.8	1.6	0.119
		Idle in neutral		10.4	12.1	1.3	0.097

[(a)] CID = cubic inch displacement

[(b)] Short Test Effectiveness = $\frac{\text{\% FF for short test}}{\text{\% FTP failures in same population}}$

Table 124. Comparison of Multiple Constituent Results for CID[(a)] = 150 and Less, by City – Predicted Population, Three Cities, Bounded Errors of Commission Method (E_c Set at 5 Percent)

Short Test	City	Test Mode	No. of Vehicles	Parameter (percent)			STE[(b)]
				E_c	E_o	FF	
Federal Short Cycle	All		95	1.1	13.7	44.2	0.763
	Chicago		32	3.1	15.6	40.6	0.722
	Houston		33	0.0	6.1	60.6	0.909
	Phoenix		30	0.0	20.0	30.0	0.600
Federal Three-Mode	All	High speed	95	6.3	39.0	19.0	0.328
		Low speed		8.4	38.8	21.0	0.351
		Idle in drive		6.3	27.4	30.5	0.527
		Idle in neutral		5.3	35.8	22.1	0.382
		Best[(c)]		5.3	28.4	29.5	0.509
	Chicago	High speed	32	6.3	34.4	21.9	0.389
		Low speed		9.4	31.3	25.0	0.444
		Idle in drive		6.3	28.1	28.1	0.500
		Idle in neutral		9.4	25.0	31.3	0.556
		Best[(c)]		6.3	28.1	28.1	0.500
	Houston	High speed	33	3.0	48.5	18.2	0.273
		Low speed		0.0	27.3	12.1	0.307
		Idle in drive		3.0	27.3	39.4	0.591
		Idle in neutral		0.0	39.4	0.0	0
		Best[(c)]		0.0	27.3	0.0	0
	Phoenix	High speed	30	10.0	33.3	16.7	0.334
		Low speed		13.3	33.3	16.7	0.334
		Idle in drive		10.0	26.7	23.3	0.466
		Idle in neutral		6.7	43.3	6.7	0.134
		Best[(c)]		10.0	30.0	20.0	0.400

(a) CID = cubic inch displacement

(b) Short Test Effectiveness = $\frac{\text{\% FF for short test}}{\text{\% FTP failures in same population}}$

(c) Best mode is: HC and CO at idle in drive; NO_x at high speed

Table 125. Comparison of HC Results for CID[a] = 151 to 259, by City — Predicted Population, Three Cities, Bounded Errors of Commission Method (E_c Set at 5 Percent)

Short Test	City	Test Mode	No. of Vehicles	Parameter (percent)			STE[b]
				E_c	E_o	FF	
Federal Short Cycle	All		54	5.0	14.0	13.3	0.487
	Chicago		19	8.3	4.4	11.0	0.714
	Houston		16	3.8	11.6	15.3	0.569
	Phoenix		19	5.0	20.1	15.1	0.429
Federal Three-Mode	All	High speed	54	5.0	23.6	3.7	0.136
		Low speed		5.0	21.3	6.0	0.220
		Idle in drive		5.0	18.8	8.4	0.309
		Idle in neutral		5.0	20.0	7.2	0.265
	Chicago	High speed	19	8.8	14.1	3.5	0.199
		Low speed		6.3	15.2	2.4	0.136
		Idle in drive		6.6	10.0	7.6	0.432
		Idle in neutral		5.8	11.8	5.8	0.330
	Houston	High speed	16	0.0	37.3	0.0	0
		Low speed		1.0	25.9	1.1	0.041
		Idle in drive		2.8	19.4	7.6	0.281
		Idle in neutral		2.8	21.5	5.5	0.204
	Phoenix	High speed	19	6.3	25.0	10.2	0.290
		Low speed		10.1	21.5	13.7	0.389
		Idle in drive		5.7	25.5	9.7	0.276
		Idle in neutral		5.9	26.0	9.2	0.261

[a] CID = cubic inch displacement

[b] Short Test Effectiveness = $\frac{\text{\% FF for short test}}{\text{\% FTP failures in same population}}$

Table 126. Comparison of CO Results for CID[(a)] = 151 to 259, by City — Predicted Population, Three Cities, Bounded Errors of Commission Method (E_c Set at 5 Percent)

Short Test	City	Test Mode	No. of Vehicles	Parameter (percent)			STE[(b)]
				E_c	E_o	FF	
Federal Short Cycle	All		54	5.0	14.6	41.0	0.737
	Chicago		19	3.1	14.0	40.5	0.743
	Houston		16	6.6	16.0	34.9	0.686
	Phoenix		19	4.0	12.7	48.1	0.791
Federal Three-Mode	All	High speed	54	5.0	51.9	6.5	0.111
		Low speed		5.0	45.0	14.1	0.239
		Idle in drive		5.0	24.7	34.8	0.585
		Idle in neutral		5.0	32.4	27.1	0.456
	Chicago	High speed	19	2.4	47.3	7.2	0.132
		Low speed		3.7	40.6	13.9	0.255
		Idle in drive		7.9	18.4	38.5	0.677
		Idle in neutral		7.4	24.0	32.9	0.578
	Houston	High speed	16	8.2	57.9	1.5	0.025
		Low speed		6.2	48.8	12.8	0.208
		Idle in drive		6.0	30.3	29.7	0.495
		Idle in neutral		6.0	41.0	19.0	0.317
	Phoenix	High speed	19	3.8	50.4	10.4	0.171
		Low speed		5.0	44.8	16.0	0.263
		Idle in drive		1.7	24.2	36.6	0.602
		Idle in neutral		1.3	30.0	30.8	0.507

(a) CID = cubic inch displacement

(b) Short Test Effectiveness = $\frac{\text{\% FF for short test}}{\text{\% FTP failures in same population}}$

Table 127. Comparison of NO_x Results for CID[a] = 151 to 259, by City – Predicted Population, Three Cities, Bounded Errors of Commission Method (E_c Set at 5 Percent)

Short Test	City	Test Mode	No. of Vehicles	Parameter (percent)			STE[b]
				E_c	E_o	FF	
Federal Short Cycle	All		54	5.0	7.5	12.5	0.625
	Chicago		19	3.4	6.8	7.1	0.511
	Houston		16	10.3	10.8	9.4	0.465
	Phoenix		19	2.4	5.5	19.8	0.783
Federal Three-Mode	All	High speed	54	5.0	15.4	4.6	0.230
		Low speed		5.0	11.1	8.9	0.445
		Idle in drive		5.0	16.7	3.3	0.165
		Idle in neutral		5.0	17.5	2.5	0.125
	Chicago	High speed	19	0.8	13.3	0.7	0.050
		Low speed		1.4	11.4	2.6	0.186
		Idle in drive		8.2	11.5	2.5	0.179
		Idle in neutral		12.1	11.3	2.7	0.193
	Houston	High speed	16	1.6	18.8	1.3	0.065
		Low speed		6.9	11.1	9.3	0.456
		Idle in drive		0.6	19.2	0.9	0.045
		Idle in neutral		0.4	19.7	0.4	0.020
	Phoenix	High speed	19	5.2	11.7	13.6	0.538
		Low speed		6.9	9.2	16.1	0.636
		Idle in drive		2.7	22.9	2.4	0.095
		Idle in neutral		0.3	25.0	0.3	0.012

[a] CID = cubic inch displacement

[b] Short Test Effectiveness = $\frac{\text{\% FF for short test}}{\text{\% FTP failures in same population}}$

Table 128. Comparison of Multiple Constituent Results for CID[a] = 151 to 259, by City — Predicted Population, Three Cities, Bounded Errors of Commission Method (E_c Set at 5 Percent)

Short Test	City	Test Mode	No. of Vehicles	Parameter (percent)			STE[b]
				E_c	E_o	FF	
Federal Short Cycle	All		54	5.6	13.0	55.6	0.810
	Chicago		19	0.0	10.5	52.6	0.834
	Houston		16	6.3	18.8	50.0	0.727
	Phoenix		19	10.5	10.5	63.2	0.858
Federal Three-Mode	All	High speed	54	1.9	55.6	13.0	0.190
		Low speed		3.7	35.2	33.3	0.486
		Idle in drive		5.6	24.1	44.4	0.648
		Idle in neutral		3.7	35.2	33.3	0.486
		Best[c]		1.9	22.2	46.3	0.676
	Chicago	High speed	19	5.3	52.6	10.5	0.166
		Low speed		10.5	36.8	26.3	0.417
		Idle in drive		15.8	10.5	52.6	0.834
		Idle in neutral		10.5	26.3	36.8	0.583
		Best[c]		5.3	15.8	47.4	0.750
	Houston	High speed	16	0.0	68.8	0.0	0
		Low speed		0.0	43.8	25.0	0.363
		Idle in drive		0.0	25.0	43.8	0.637
		Idle in neutral		0.0	43.8	25.0	0.363
		Best[c]		0.0	18.8	50.0	0.727
	Phoenix	High speed	19	0.0	47.4	26.3	0.357
		Low speed		0.0	26.3	47.4	0.643
		Idle in drive		0.0	36.8	36.8	0.500
		Idle in neutral		0.0	36.8	36.8	0.500
		Best[c]		0.0	31.6	42.1	0.571

[a] CID = cubic inch displacement

[b] Short Test Effectiveness = $\frac{\text{\% FF for short test}}{\text{\% FTP failures in same population}}$

[c] Best mode is: HC and CO at idle in drive; NO_x at high speed

Table 129. Comparison of HC Results for CID[a] = 260 and Greater, by City — Predicted Population, Three Cities, Bounded Errors of Commission Method (E_c Set at 5 Percent)

Short Test	City	Test Mode	No. of Vehicles	Parameter (percent)			STE[b]
				E_c	E_o	FF	
Federal Short Cycle	All		151	5.0	12.5	20.4	0.620
	Chicago		49	3.7	12.2	17.0	0.582
	Houston		51	3.8	10.2	27.9	0.732
	Phoenix		51	7.4	14.0	16.6	0.542
Federal Three-Mode	All	High speed	151	5.0	27.0	5.7	0.174
		Low speed		5.0	24.7	8.0	0.245
		Idle in drive		5.0	18.3	14.6	0.444
		Idle in neutral		5.0	19.6	13.3	0.404
	Chicago	High speed	49	6.8	22.3	6.2	0.218
		Low speed		6.6	19.9	8.6	0.302
		Idle in drive		7.1	18.1	11.0	0.378
		Idle in neutral		6.4	19.8	9.3	0.320
	Houston	High speed	51	1.7	33.1	5.0	0.131
		Low speed		1.8	30.7	7.4	0.194
		Idle in drive		2.4	21.9	16.2	0.425
		Idle in neutral		4.3	21.2	16.9	0.444
	Phoenix	High speed	51	6.8	26.1	4.5	0.147
		Low speed		6.8	24.4	6.2	0.203
		Idle in drive		4.0	13.1	17.6	0.573
		Idle in neutral		2.4	16.9	13.7	0.448

[a] CID = cubic inch displacement

[b] $\text{Short Test Effectiveness} = \frac{\text{\% FF for short test}}{\text{\% FTP failures in same population}}$

Table 130. Comparison of CO Results for CID(a) = 260 and Greater, by City – Predicted Population, Three Cities, Bounded Errors of Commission Method (E_c Set at 5 Percent)

Short Test	City	Test Mode	No. of Vehicles	Parameter (percent)			STE(b)
				E_c	E_o	FF	
Federal Short Cycle	All		151	5.0	13.0	44.2	0.773
	Chicago		49	5.2	15.0	44.5	0.748
	Houston		51	4.1	9.3	45.9	0.832
	Phoenix		51	5.0	14.8	43.0	0.744
Federal Three-Mode	All	High speed	151	5.0	41.4	17.4	0.296
		Low speed		5.0	38.0	20.9	0.355
		Idle in drive		5.0	17.8	42.1	0.703
		Idle in neutral		5.0	18.8	41.3	0.687
	Chicago	High speed	49	7.4	33.2	26.3	0.442
		Low speed		6.3	32.0	27.4	0.461
		Idle in drive		5.8	21.4	38.1	0.640
		Idle in neutral		6.1	22.9	36.5	0.615
	Houston	High speed	51	1.7	47.8	11.5	0.194
		Low speed		3.1	42.9	16.6	0.279
		Idle in drive		3.8	16.8	45.6	0.731
		Idle in neutral		3.0	17.8	45.3	0.718
	Phoenix	High speed	51	5.6	43.0	14.8	0.256
		Low speed		4.6	38.8	19.0	0.329
		Idle in drive		5.9	16.5	41.4	0.715
		Idle in neutral		6.4	17.0	40.9	0.706

(a) CID = cubic inch displacement

(b) Short Test Effectiveness = $\frac{\text{\% FF for short test}}{\text{\% FTP failures in same population}}$

Table 131. Comparison of NO_x Results for CID[a] = 260 and Greater, by City – Predicted Population, Three Cities, Bounded Errors of Commission Method (E_c Set at 5 Percent)

Short Test	City	Test Mode	No. of Vehicles	Parameter (percent)			STE[b]
				E_c	E_o	FF	
Federal Short Cycle	All		151	5.0	11.5	13.3	0.536
	Chicago		49	5.2	9.5	13.8	0.592
	Houston		51	4.2	16.3	13.0	0.444
	Phoenix		51	5.7	8.8	12.9	0.594
Federal Three-Mode	All	High speed	151	5.0	16.3	8.5	0.342
		Low speed		5.0	19.4	5.4	0.218
		Idle in drive		5.0	21.5	3.2	0.130
		Idle in neutral		5.0	20.8	4.0	0.161
	Chicago	High speed	49	.6	24.4	2.2	0.083
		Low speed		3.2	19.9	3.4	0.146
		Idle in drive		4.4	20.0	3.2	0.138
		Idle in neutral		3.2	20.2	3.0	0.129
	Houston	High speed	51	2.8	22.3	7.1	0.241
		Low speed		3.7	24.5	4.9	0.167
		Idle in drive		4.3	24.7	4.7	0.160
		Idle in neutral		5.9	23.1	6.2	0.212
	Phoenix	High speed	51	8.8	10.0	11.7	0.539
		Low speed		8.2	13.6	8.1	0.373
		Idle in drive		5.2	20.3	1.4	0.065
		Idle in neutral		3.5	19.7	2.0	0.092

(a) CID = cubic inch displacement

(b) Short Test Effectiveness = $\frac{\text{\% FF for short test}}{\text{\% FTP failures in same population}}$

Table 132. Comparison of Multiple Constituent Results for CID[a] = 260 and Greater, by City — Predicted Population, Three Cities, Bounded Errors of Commission Method (E_c Set at 5 Percent)

Short Test	City	Test Mode	No. of Vehicles	Parameter (percent)			STE[b]
				E_c	E_o	FF	
Federal Short Cycle	All		151	8.0	6.6	62.3	0.904
	Chicago		49	10.2	10.2	63.3	0.861
	Houston		51	7.8	3.9	60.8	0.940
	Phoenix		51	5.9	5.9	62.8	0.914
Federal Three-Mode	All	High speed	151	2.0	38.4	30.5	0.443
		Low speed		2.7	33.8	35.1	0.509
		Idle in drive		6.0	19.2	49.7	0.721
		Idle in neutral		5.3	17.9	51.0	0.740
		Best[c]		4.0	19.9	49.0	0.711
	Chicago	High speed	49	4.1	38.8	34.7	0.472
		Low speed		4.1	34.7	38.8	0.528
		Idle in drive		4.1	28.6	44.9	0.611
		Idle in neutral		6.1	28.6	44.9	0.611
		Best[c]		4.1	34.7	38.8	0.528
	Houston	High speed	51	0.0	39.2	25.5	0.394
		Low speed		2.0	37.3	27.5	0.424
		Idle in drive		7.8	9.8	54.9	0.849
		Idle in neutral		3.9	7.8	56.9	0.879
		Best[c]		3.9	11.8	52.9	0.818
	Phoenix	High speed	51	2.0	37.3	31.4	0.457
		Low speed		2.0	29.4	39.2	0.571
		Idle in drive		5.9	19.6	49.0	0.714
		Idle in neutral		5.9	17.7	51.0	0.742
		Best[c]		3.9	13.7	54.9	0.800

[a] CID = cubic inch displacement

[b] Short Test Effectiveness = $\frac{\text{\% FF for short test}}{\text{\% FTP failures in same population}}$

[c] Best mode is: HC and CO at idle in drive; NO_x at high speed

Table 133. Contingency Table

		True = FTP		
		Pass	Fail	Total
Predicted = Short Test	Pass	a	b	a + b
	Fail	c	d	c + d
	Total	a + c	b + d	n = a + b + c + d

a = number of correctly passed vehicles (PP)

b = number of errors of omission (E_o)

c = number of errors of commission (E_c)

d = number of correctly failed vehicles (FF)

Sensitivity = $a/(a + c)$
Specificity = $b/(b + d)$
False positive error = $b/(a + b)$
False negative error = $c/(c + d)$

$$\text{Correlation index} = \frac{ad - bc}{[(a + b)(a + c)(b + d)(c + d)]^{1/2}}$$

Table 134. Maintenance Options and Adjustment Procedures for Each Version of the Maintenance Model

Options and Procedures	Version of Maintenance Model		
	1	2	3
HC, CO, NO_x Adjusted Independently		x	x
NO_x Adjustment Independent HC and CO Adjustment Coupled	x		
Emission Values Adjusted to FTP Standard	x	x	
Emission Values Adjusted to Equivalent ST Standard			x

Table 135. Average Deterioration Rates Used in 207(b) Effectiveness Simulation

Data Source	Rate of Deterioration in Grams/Mile Per 1000 Miles		
	HC	CO	NO_x
Certification(a)	0.014	0.084	0.0
EFP(b)	0.072	0.800	0.0

(a) Unpublished Communication from EPA on 1975 Certification Results

(b) Automobile Exhaust Emission Surveillance Analysis of the FY 73 Program, EPA Report EPA-460/3-75-007, July 1975

Table 136. Annual Mileage Accumulations Used in 207(b) Effectiveness Simulation

Age of Vehicles In Years	Number of Years In Program	Accumulated Average Mileage(a)	
		Annual	Cumulative
1	0	17,500	17,500
2	1	16,100	33,600
3	2	13,200	46,800
4(b)	3(b)	3,200	50,000

(a) Nationwide Personnal Transportation Study; Annual Miles of Automobile Travel, Report No. 2, April 1972, U.S. Department of Transportation

(b) Not a full year - simulation stops at 50,000 miles

Table 137. Initial Simulated Fleet Statistics(a)

CID(b)	No. of Vehicles	Average Emissions Grams/Mile					
		HC		CO		NO_x	
		Mean	SE (c)	Mean	SE	Mean	SE
Less than 150	951	1.82	.837	22.5	11.21	2.12	1.051
151 to 259	540	1.82	.810	29.4	20.99	2.42	.902
Greater than 260	1509	1.94	1.018	35.9	35.60	2.56	1.051

(a) After initial correction to 17,500 miles

(b) CID = cubic inch displacement

(c) SE = standard error

Table 138. 207(b) ST[a] Cut-Points for Each Engine Family

CID[b]	Cut-Points[c] in PPM		
	HC	CO	NO_x
150 and Less	219	18,332	2,805
151 to 259	213	7,062	1,395
260 and Greater	151	2,655	1,986

[a] The ST was defined from the Federal Three-Mode with HC and CO idle in drive, and NO_x in high speed (low speed NO_x was used for 151 to 259 CID group)

[b] CID - cubic inch displacement

[c] Cut-points were computed from 300 car data using a 5 percent E_c rate on each pollutant for each engine class

Table 139. 207(b) Program Efficiencies with Maintenance Version 1

Maintenance Period of Effectiveness	Number of Years Since The 1st Inspection	Estimated Program Efficiencies in Percent		
		Cumulative		
		HC	CO	NO_x
12	1	22.7	32.4	2.05
	2	31.6	39.0	1.81
	3 (a)	34.6	42.5	2.00
9	1	19.5	26.2	1.25
	2	26.7	31.9	1.04
	3 (a)	30.0	36.1	1.29
6	1	14.6	18.7	0.46
	2	19.8	23.0	0.22
	3 (a)	23.3	27.6	0.50

(a) Not a full year. Program ended at 50,000 miles

Table 140. 207(b) Program Efficiencies with Maintenance Version 2

Maintenance Period of Effectiveness	Number of Years Since The 1st Inspection	Estimated Program Efficiencies in Percent		
		Cumulative		
		HC	CO	NO_x
12	1	22.7	29.7	2.05
	2	31.6	35.9	1.81
	3[(a)]	34.6	39.1	2.00
9	1	19.5	24.2	1.25
	2	26.7	29.4	1.04
	3[(a)]	30.0	33.0	1.29
6	1	14.6	17.3	0.46
	2	19.8	21.2	0.22
	3[(a)]	23.3	25.1	0.50

(a) Not a full year. Program ended at 50,000 miles

Table 141. 207(b) Program Efficiencies with Maintenance Version 3

Maintenance Period of Effectiveness	Number of Years Since The 1st Inspection	Estimated Program Efficiencies in Percent Cumulative HC	CO	NO_x
12	1	21.1	29.0	1.78
	2	30.0	35.2	1.53
	3(a)	32.9	38.3	1.70
9	1	18.4	23.6	1.05
	2	25.4	28.9	0.82
	3(a)	28.5	32.3	1.05
6	1	13.8	17.0	0.32
	2	18.9	20.8	0.08
	3(a)	22.1	24.6	0.33

(a) Not a full year. Program ended at 50,000 miles

Table 142. FTP Values Equivalent to 207(b) ST Cut-Points

CID	Equivalent ST Cut-Points - Grams/Mile		
	HC	CO	NO_x
150 and Less	1.574	18.084	3.100
151 to 259	1.633	16.66	3.100
260 and Greater	1.809	15.0	3.262

Table 143. I/M ST(a) Cut-Points for Each Engine Family

CID(b)	Cut-Points(c) in PPM		
	HC	CO	NO_x
150 and Less	269	17105	2823
151 to 259	269	17105	2823
260 and Greater	269	17105	2823

(a) The ST was defined from the Federal Three-Mode with HC and CO idle in drive, and NO_x at high speed

(b) CID = cubic inch displacement

(c) Cut-points were computed from the 300 car data set using a 33.33 percent total failure rate on 300 cars

Table 144. I/M Program Efficiencies with Maintenance Version 1

Maintenance Period of Effectiveness	Number of Years Since The 1st Inspection	Estimated Program Efficiencies in Percent		
		Cumulative		
		HC	CO	NO_x
12	1	16.4	24.3	1.59
	2	24.0	30.3	1.58
	3(a)	27.0	33.8	1.78
9	1	14.1	19.5	1.04
	2	20.1	24.5	1.03
	3(a)	23.2	28.5	1.28
6	1	10.5	13.8	0.50
	2	14.8	17.6	0.45
	3(a)	18.1	21.8	0.73

(a) Not a full year. Program ended at 50,000 miles

Table 145. I/M Program Efficiencies with Maintenance Version 2

Maintenance Period of Effectiveness	Number Years Since The 1st Inspection	Estimated Program Efficiencies in Percent		
		Cumulative		
		HC	CO	NO_x
12	1	16.4	22.2	1.59
	2	24.0	27.7	1.58
	3[a]	27.0	30.8	1.78
9	1	14.1	18.0	1.04
	2	20.1	22.5	1.03
	3[a]	23.2	25.9	1.28
6	1	10.5	12.8	0.50
	2	14.8	16.2	0.45
	3[a]	18.1	19.7	0.73

[a] Not a full year. Program ended at 50,000 miles

Table 146. I/M Program Efficiencies with Maintenance Version 3

Maintenance Period of Effectiveness	Number of Years Since The 1st Inspection	Estimated Program Efficiencies in Percent Cumulative HC	CO	NO_x
12	1	14.3	18.4	1.04
	2	21.2	23.6	0.99
	3[a]	23.7	26.1	1.13
9	1	12.5	15.1	0.63
	2	17.9	19.3	0.58
	3[a]	20.3	22.0	0.76
6	1	9.4	10.9	0.23
	2	13.3	14.0	0.15
	3[a]	15.7	16.8	0.34

[a] Not a full year. Program ended at 50,000 miles

Table 147. FTP Values Equivalent to I/M ST Cut-Points

CID	Equivalent ST Cut-Points - Grams/Mile		
	HC	CO	NO_x
150 and Less	1.71	17.66	3.10
151 to 259	1.84	21.82	3.79
260 and Greater	2.69	32.51	4.06

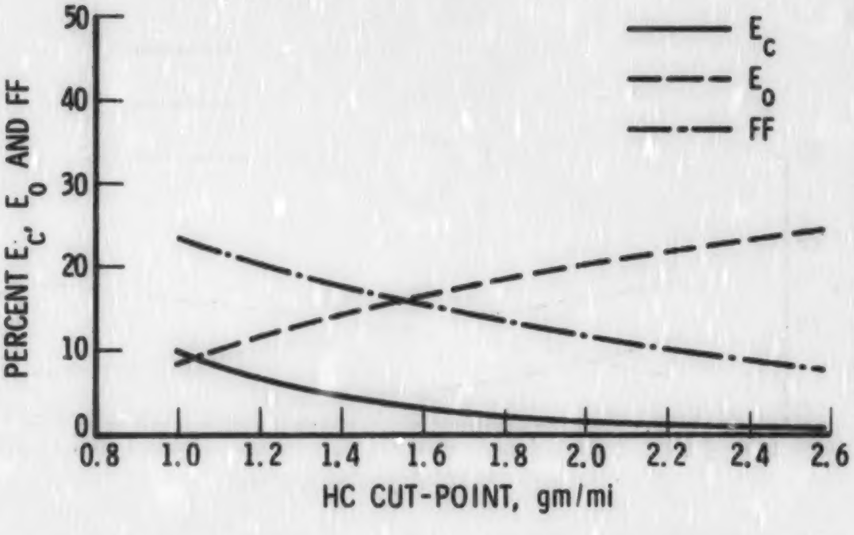


Figure 1. Variation of E_C, E_O, and FF with HC Cut-point; All Three Cities; Federal Short Cycle; Bounded Errors of Commission Method

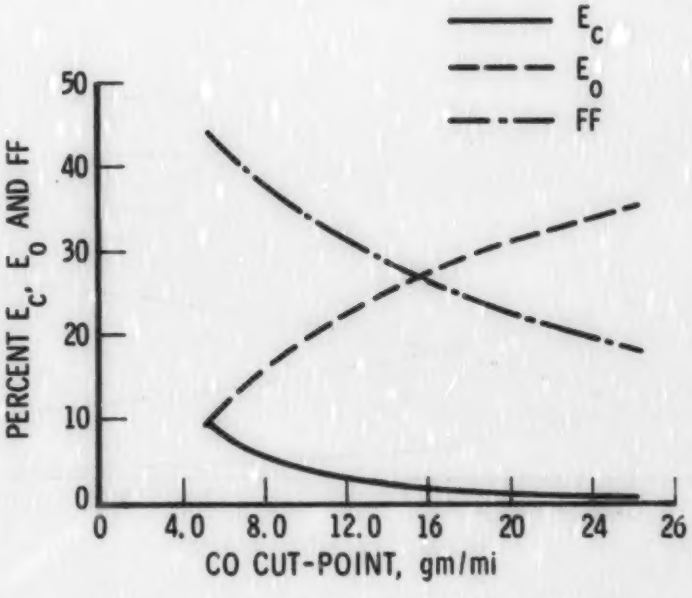


Figure 2. Variation of E_C, E_O, and FF with CO Cut-point; All Three Cities; Federal Short Cycle; Bounded Errors of Commission Method

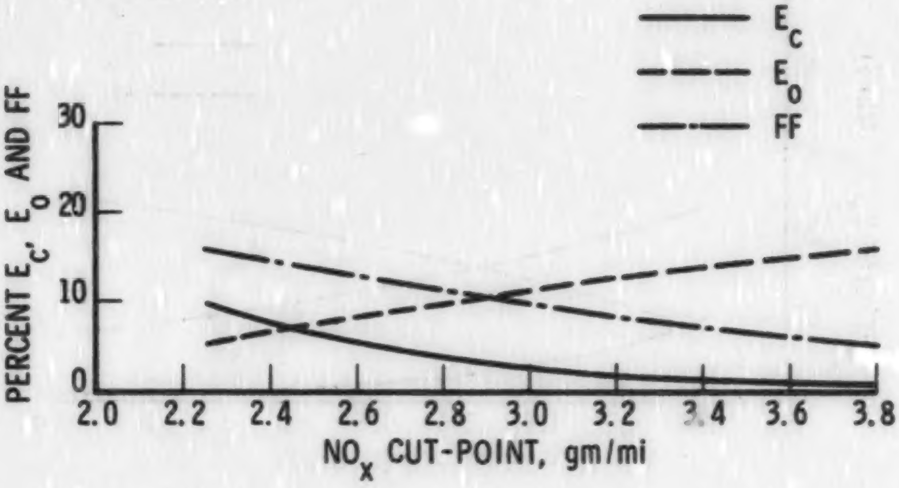


Figure 3. Variation of E_c, E_o, and FF with NO_x Cut-point; All Three Cities; Federal Short Cycle; Bounded Errors of Commission Method

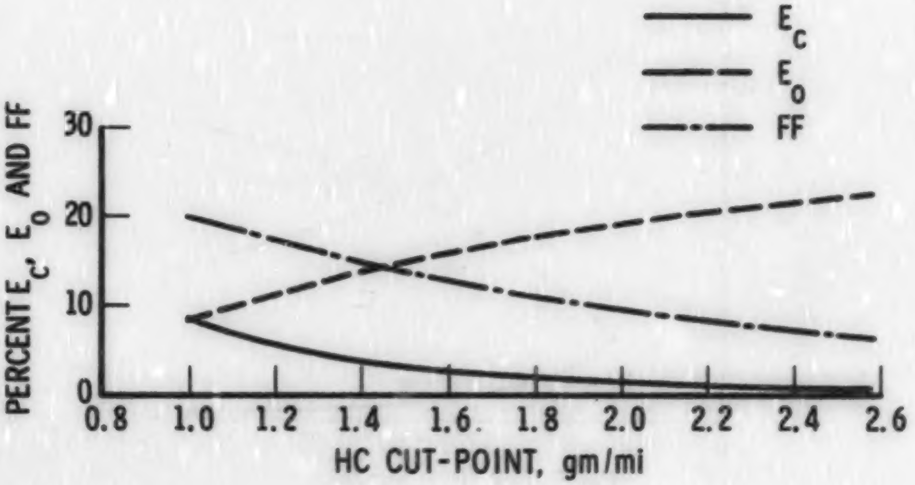


Figure 4. Variation of E_c, E_o, and FF with HC Cut-point; Chicago, Federal Short Cycle, Bounded Errors of Commission Method

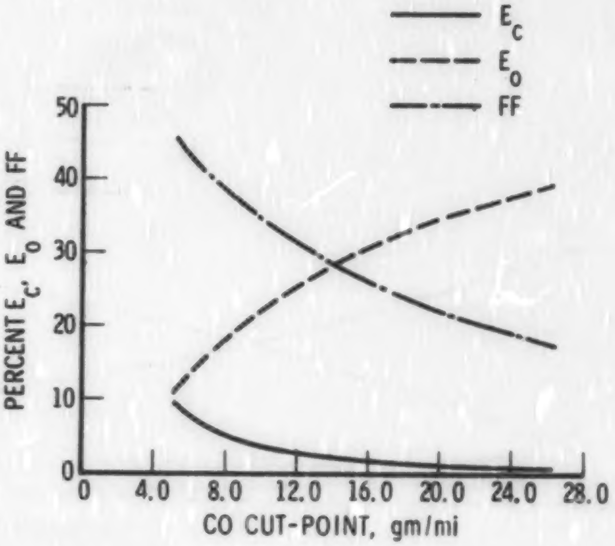


Figure 5. Variation of E_c, E_o, and FF with CO Cut-point; Chicago; Federal Short Cycle; Bounded Errors of Commission Method

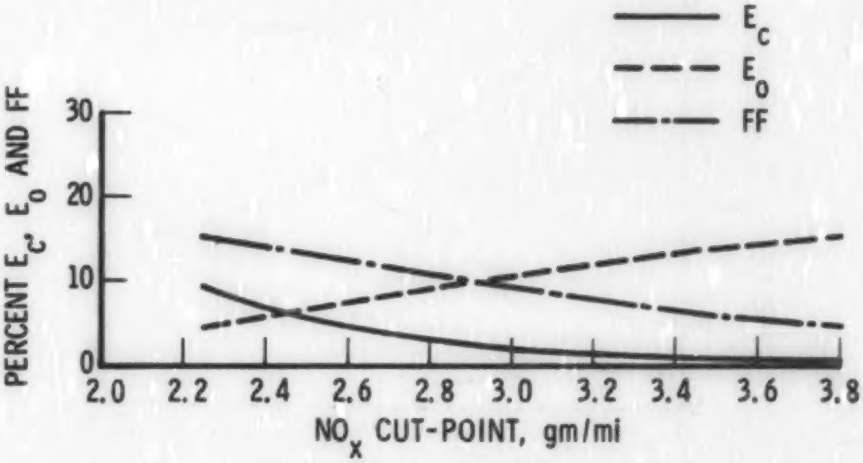


Figure 6. Variation of E_c, E_o, and FF with NO_x Cut-point; Chicago; Federal Short Cycle; Bounded Errors of Commission Method

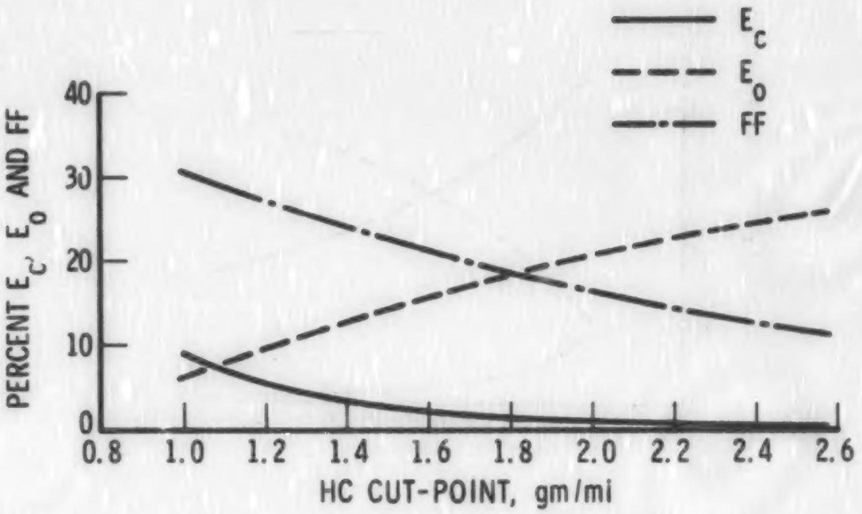


Figure 7. Variation of E_c, E_o, and FF with HC Cut-point; Houston; Federal Short Cycle; Bounded Errors of Commission Method

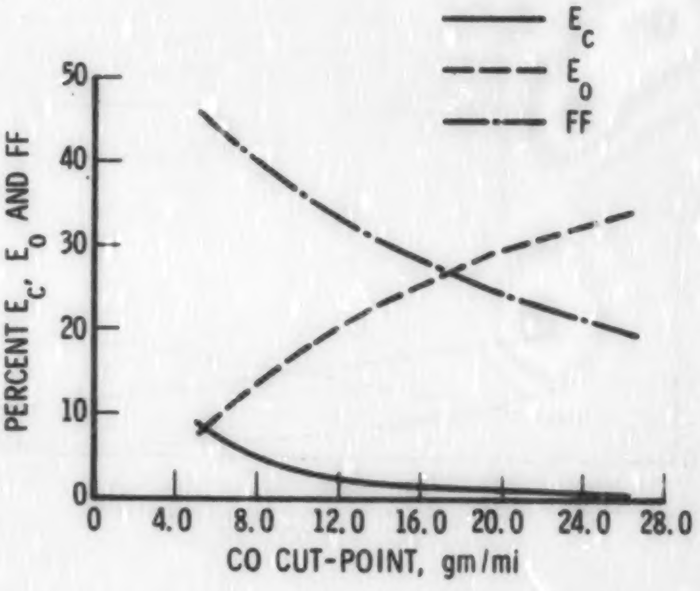


Figure 8. Variation of E_c, E_o, and FF with CO Cut-point; Houston; Federal Short Cycle; Bounded Errors of Commission Method

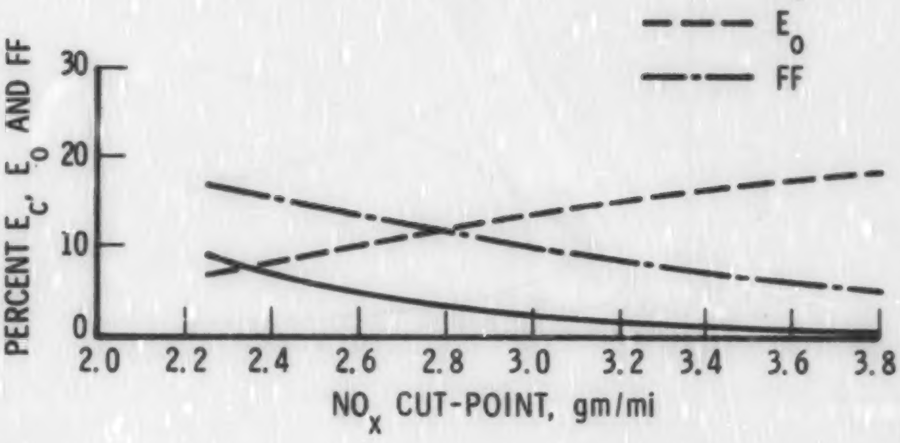


Figure 9. Variation of E_c, E_o, and FF with NO_x Cut-point; Houston; Federal Short Cycle; Bounded Errors of Commission Method

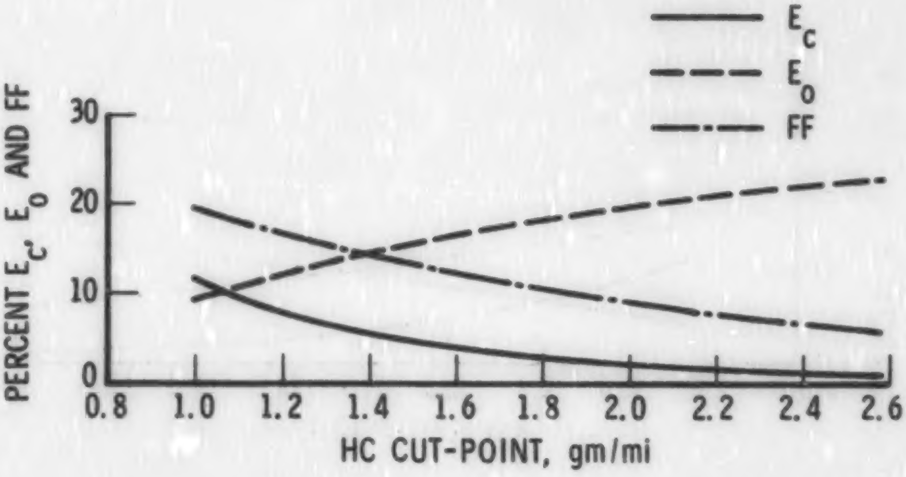


Figure 10. Variation of E_c, E_o, and FF with HC Cut-point; Phoenix; Federal Short Cycle; Bounded Errors of Commission Method

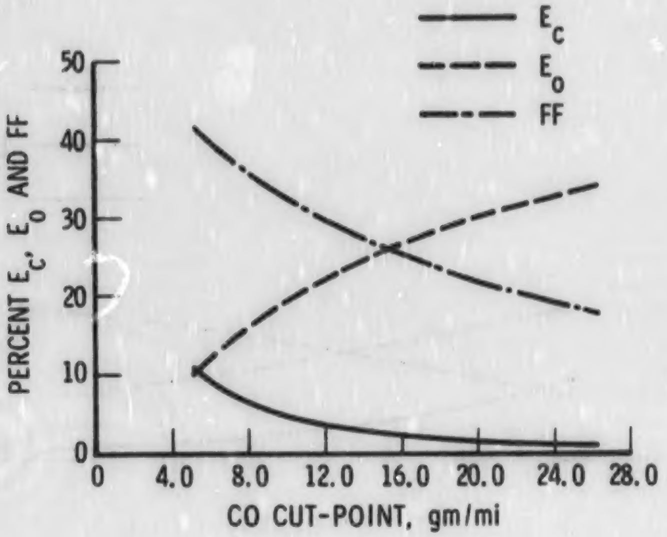


Figure 11. Variation of E_C, E_O, and FF with CO Cut-point; Phoenix; Federal Short Cycle; Bounded Errors of Commission Method

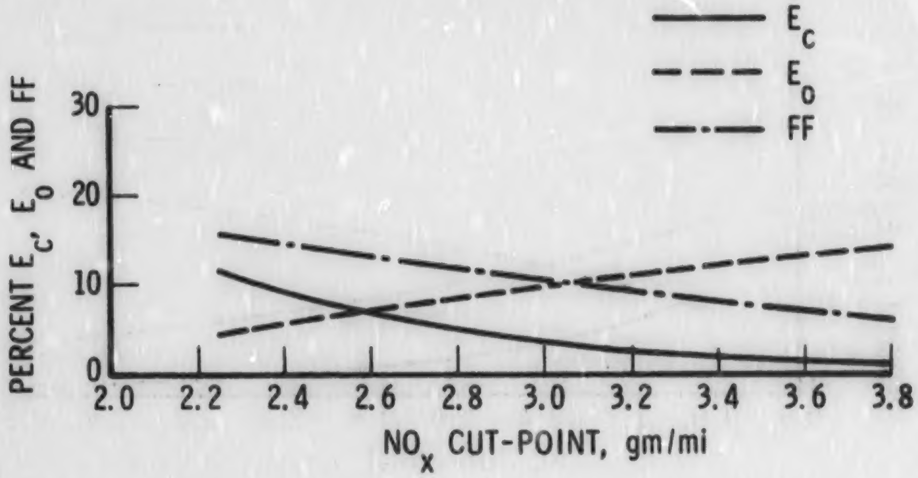


Figure 12. Variation of E_C, E_O, and FF with NO_x Cut-point; Phoenix; Federal Short Cycle; Bounded Errors of Commission Method

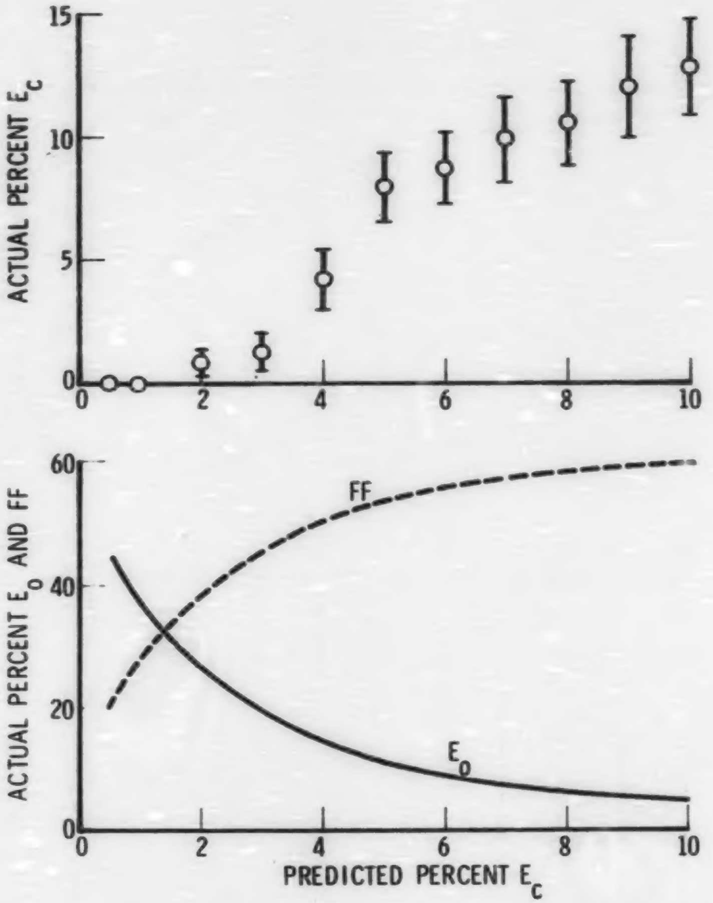


Figure 13. Variation of Actual E_c, E_o, and FF with Predicted E_c; Federal Short Cycle; All Three Cities

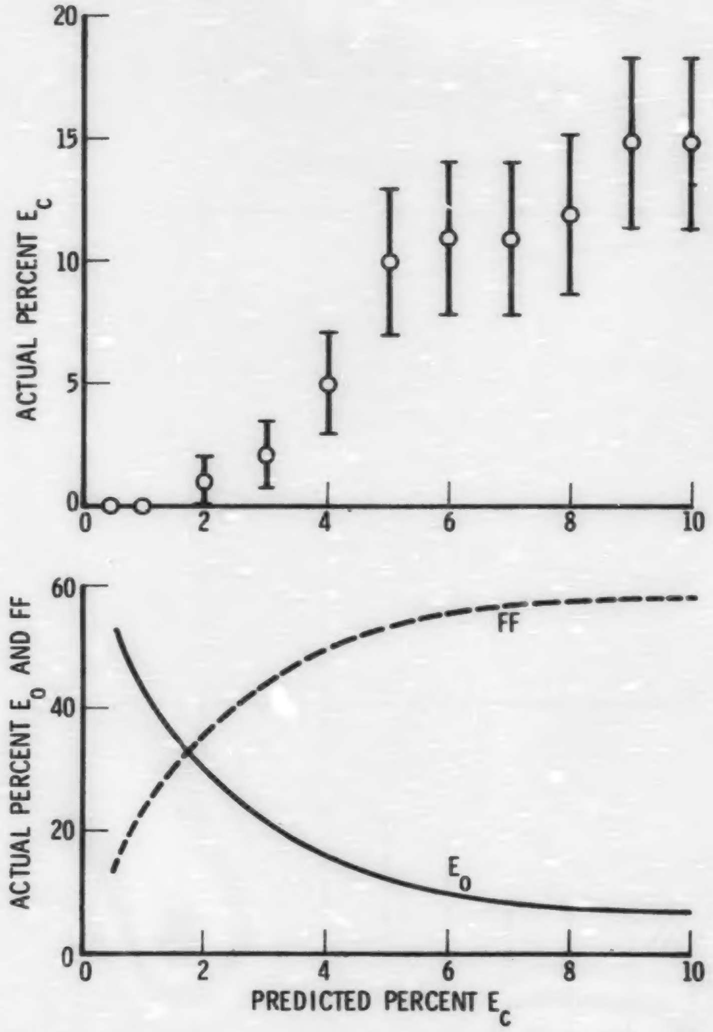


Figure 14. Variation of Actual E_c, E_o, and FF with Predicted E_c; Federal Short Cycle; Chicago

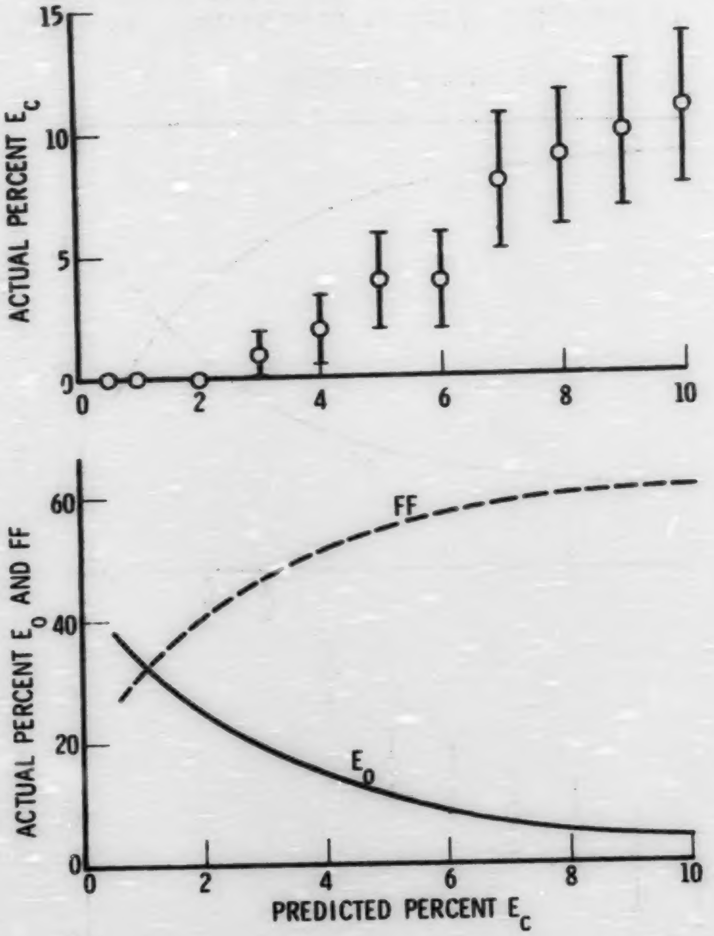


Figure 15. Variation of Actual E_c, E_o, and FF with Predicted E_c; Federal Short Cycle; Houston

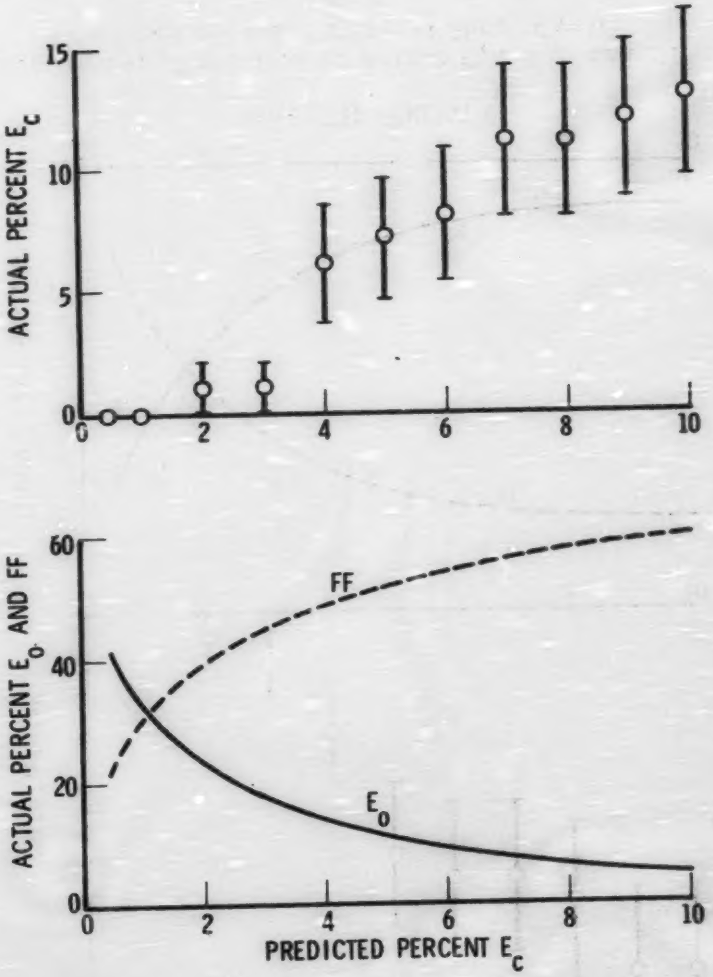


Figure 16. Variation of Actual E_c, E_o, and FF with Predicted E_c; Federal Short Cycle; Phoenix

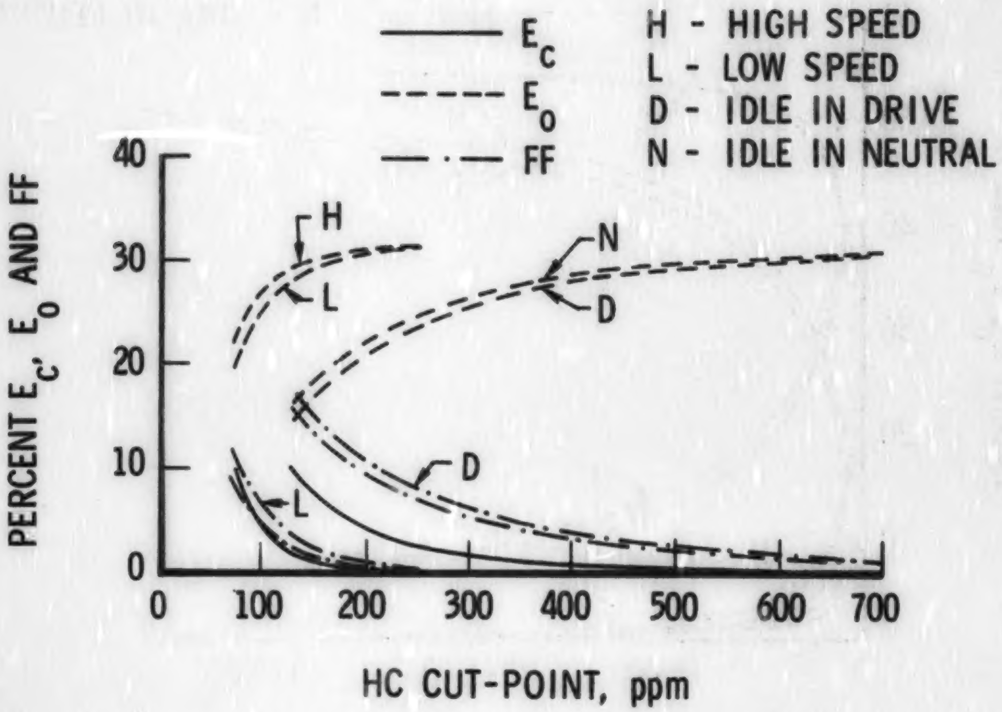


Figure 17. Variation of E_C, E_O, and FF with HC Cut-point; All Three Cities; Federal Three-Mode; Bounded Errors of Commission Method

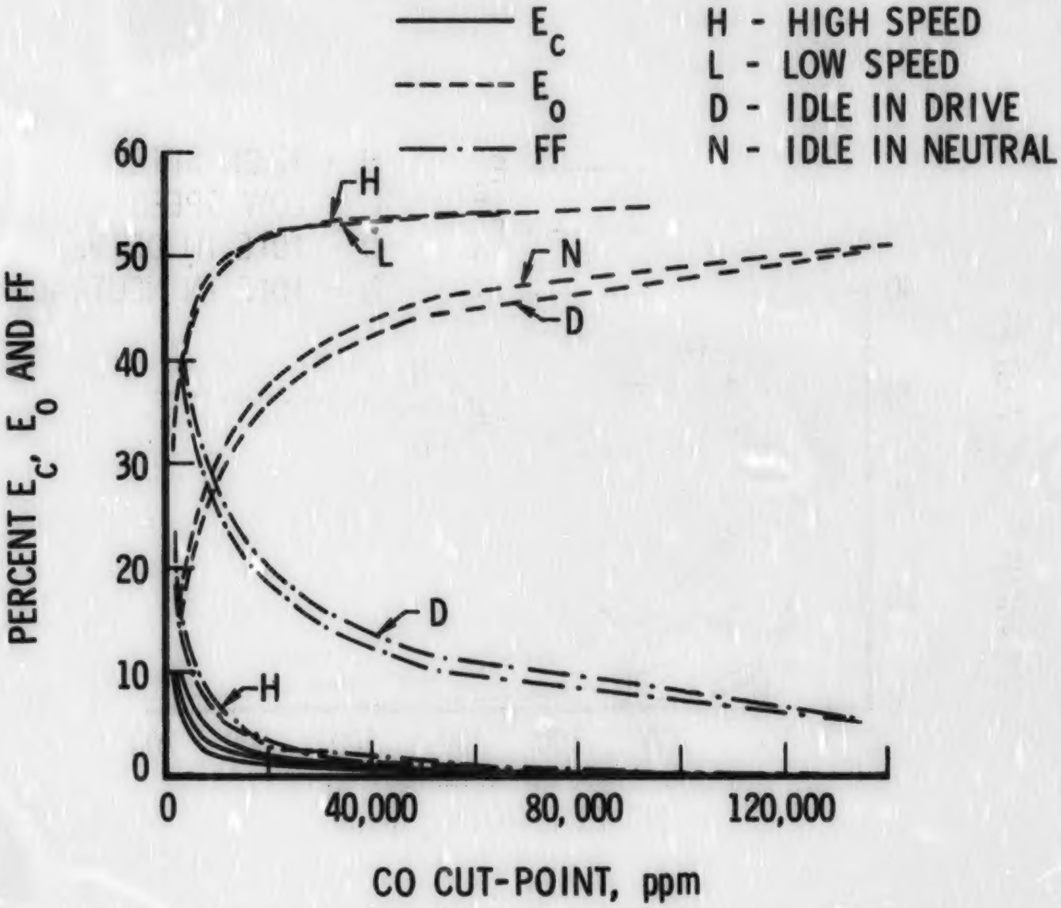


Figure 18. Variation of E_c, E_o, and FF with CO Cut-point; All Three Cities; Federal Three-Mode; Bounded Errors of Commission Method

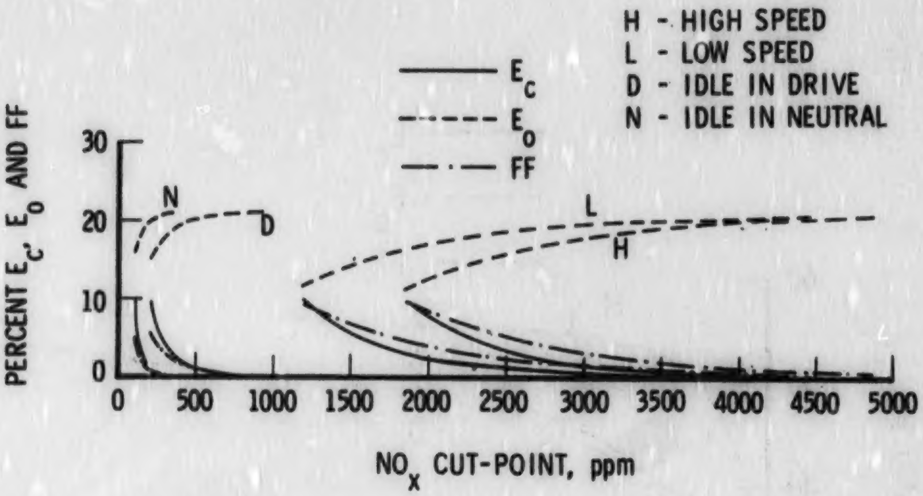


Figure 19. Variation of E_C, E_O, and FF with NO_x Cut-point; All Three Cities; Federal Three-Mode; Bounded Errors of Commission Method

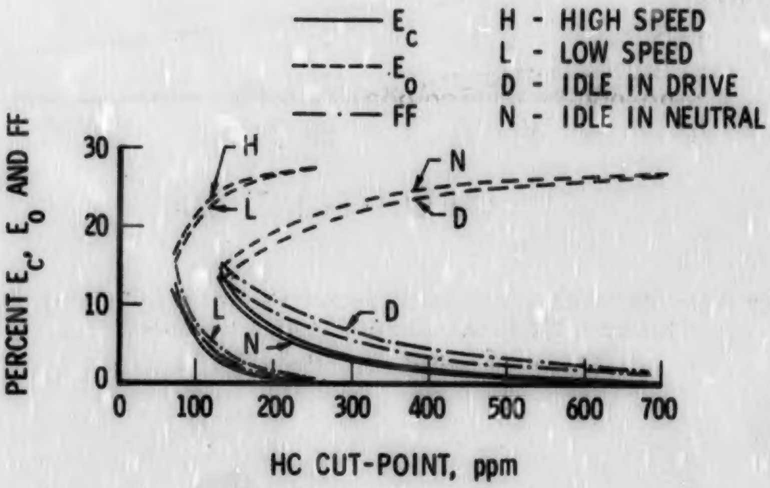


Figure 20. Variation of E_C, E_O, and FF with HC Cut-point; Chicago; Federal Three-Mode; Bounded Errors of Commission Method

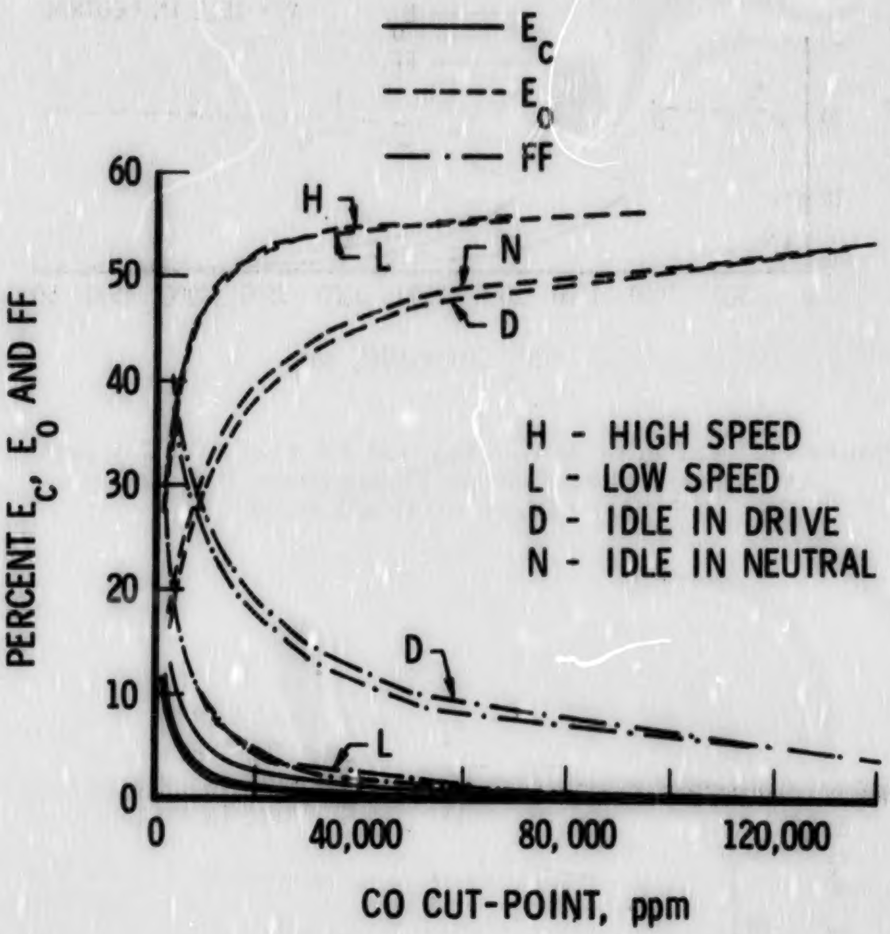


Figure 21. Variation of E_C, E_O, and FF with CO Cut-point; Chicago; Federal Three-Mode; Bounded Errors of Commission Method

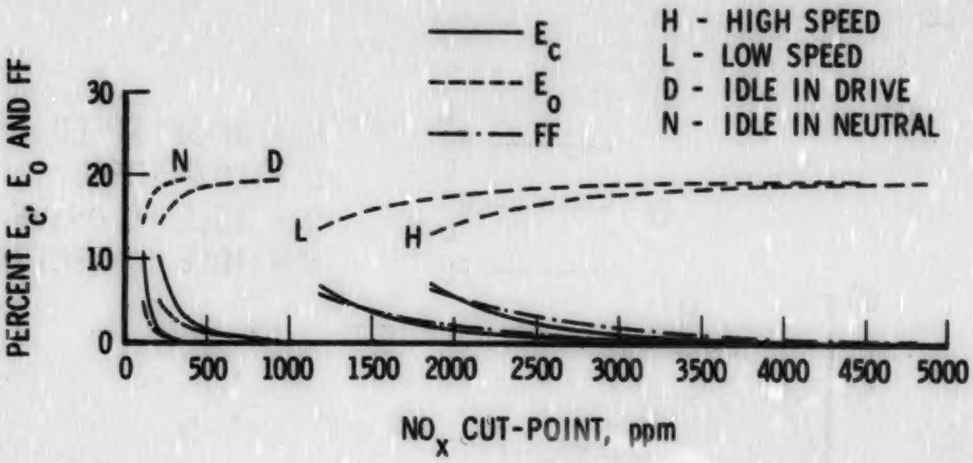


Figure 22. Variation of E_c, E_o, and FF with NO_x Cut-point; Chicago; Federal Three-Mode; Bounded Errors of Commission Method

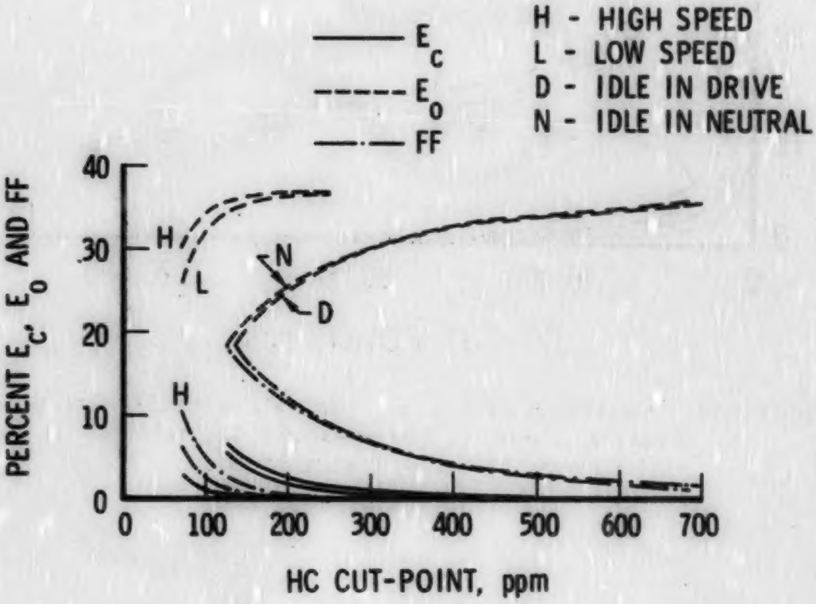


Figure 23. Variation of E_c, E_o, and FF with HC Cut-point; Houston; Federal Three-Mode; Bounded Errors of Commission Method

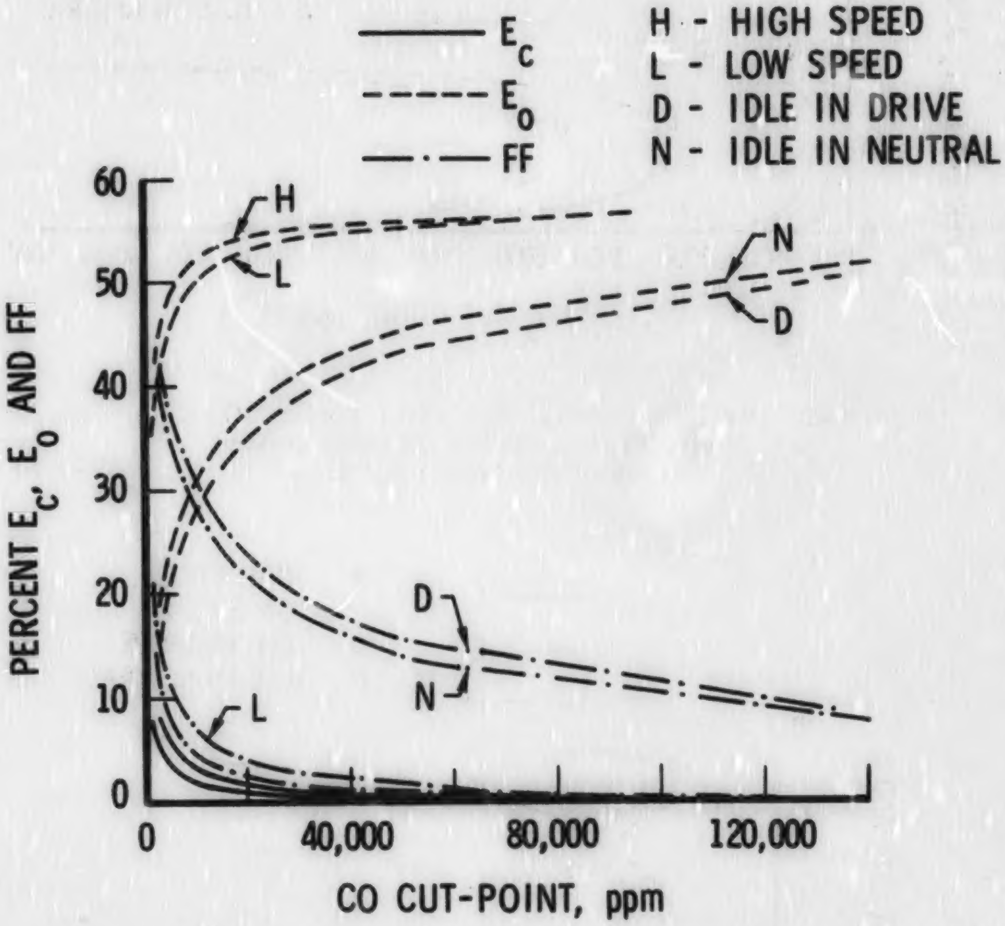


Figure 24. Variation of E_C, E_O, and FF with CO Cut-point; Houston; Federal Three-Mode; Bounded Errors of Commission Method

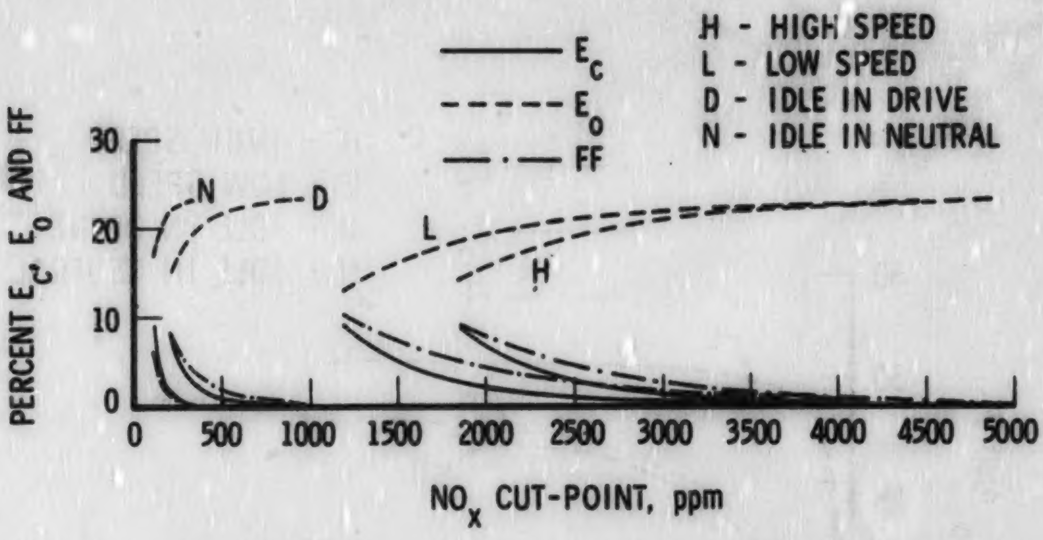


Figure 25. Variation of E_C, E_O, and FF with NO_x Cut-point; Houston; Federal Three-Mode; Bounded Errors of Commission Method

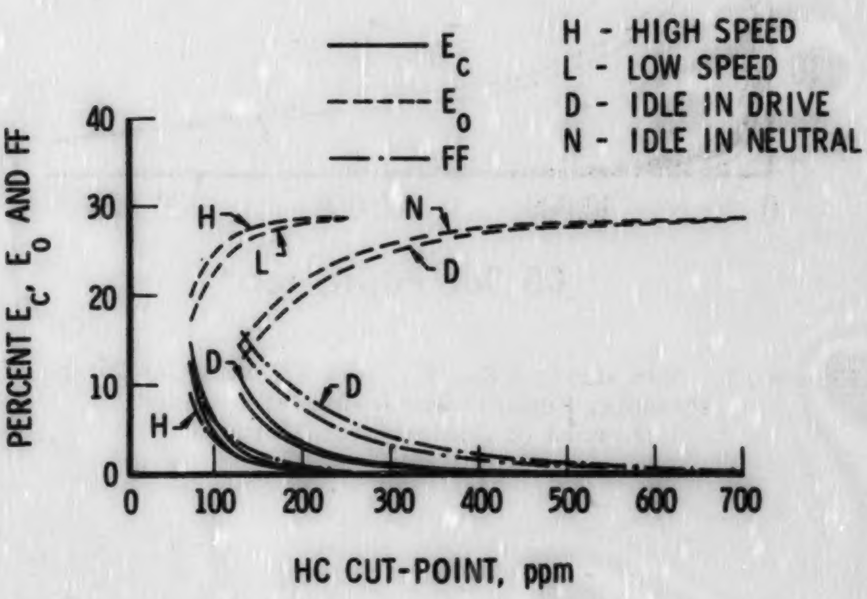


Figure 26. Variation of E_C, E_O, and FF with HC Cut-Point; Phoenix; Federal Three-Mode; Bounded Errors of Commission Method

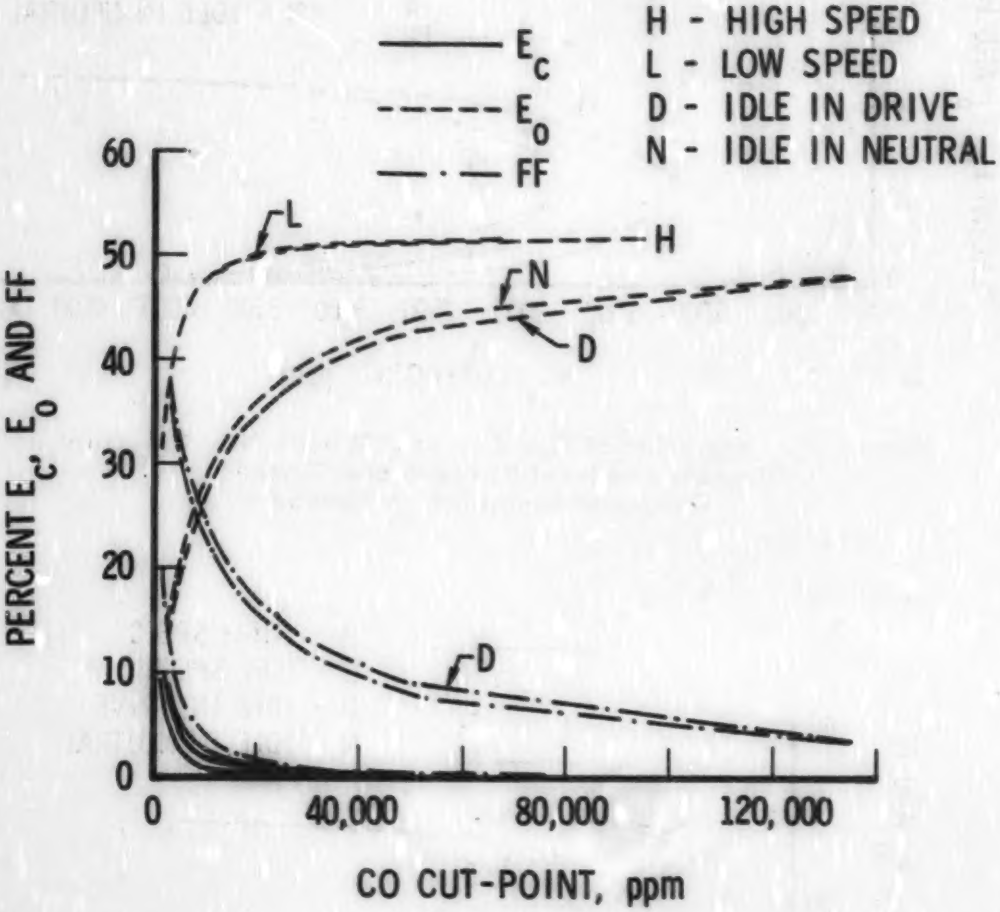


Figure 27. Variation of E_c, E_o, and FF with CO Cut-point; Phoenix; Federal Three-Mode; Bounded Errors of Commission Method

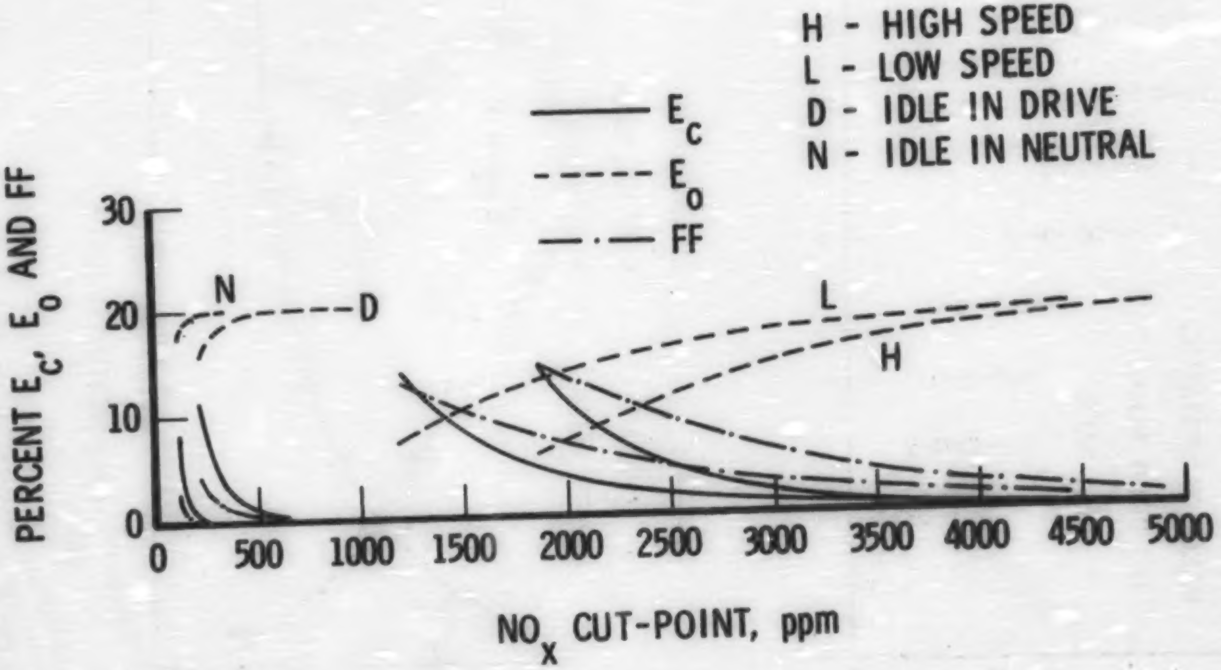


Figure 28. Variation of E_c, E_o, and FF with NO_x Cut-point; Phoenix; Federal Three-Mode; Bounded Errors of Commission Method

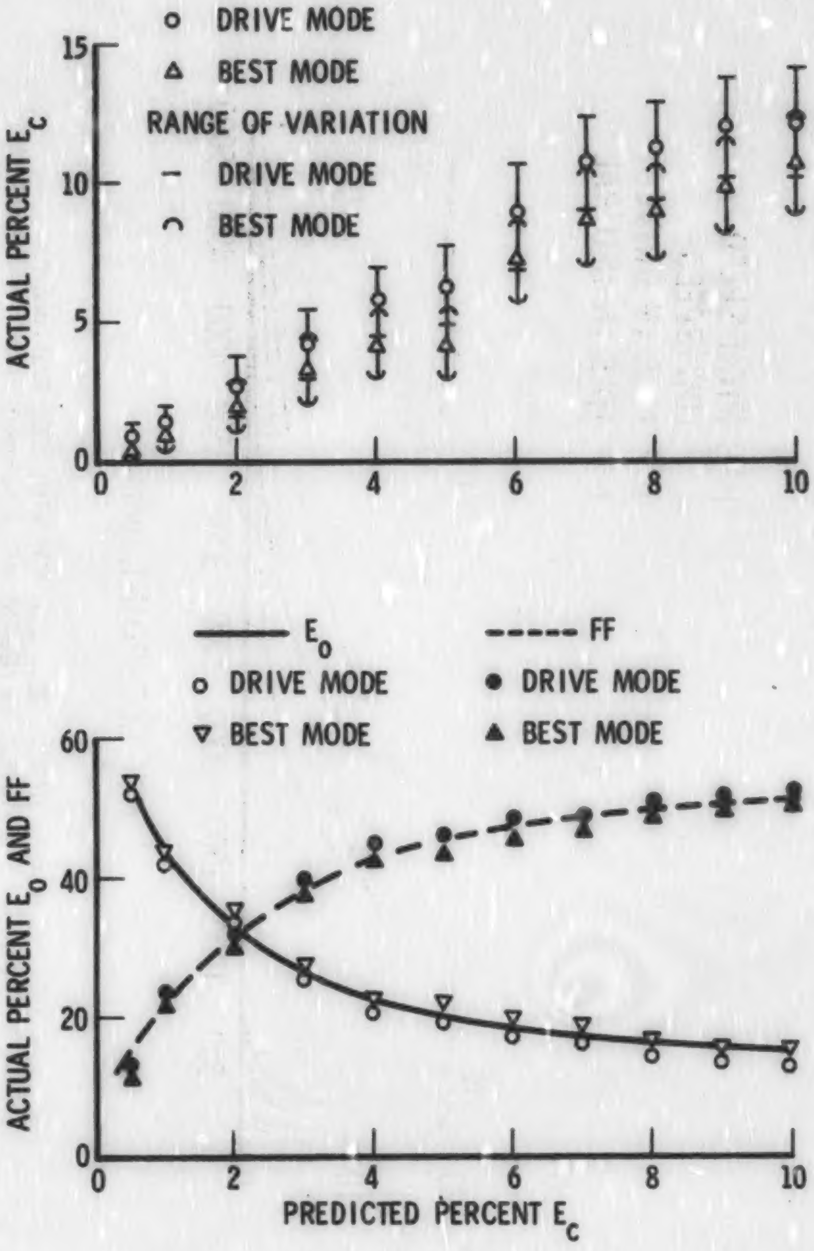


Figure 29. Variation of Actual E_c, E_o, and FF with Predicted E_c; Federal Three-Mode; All Three Cities

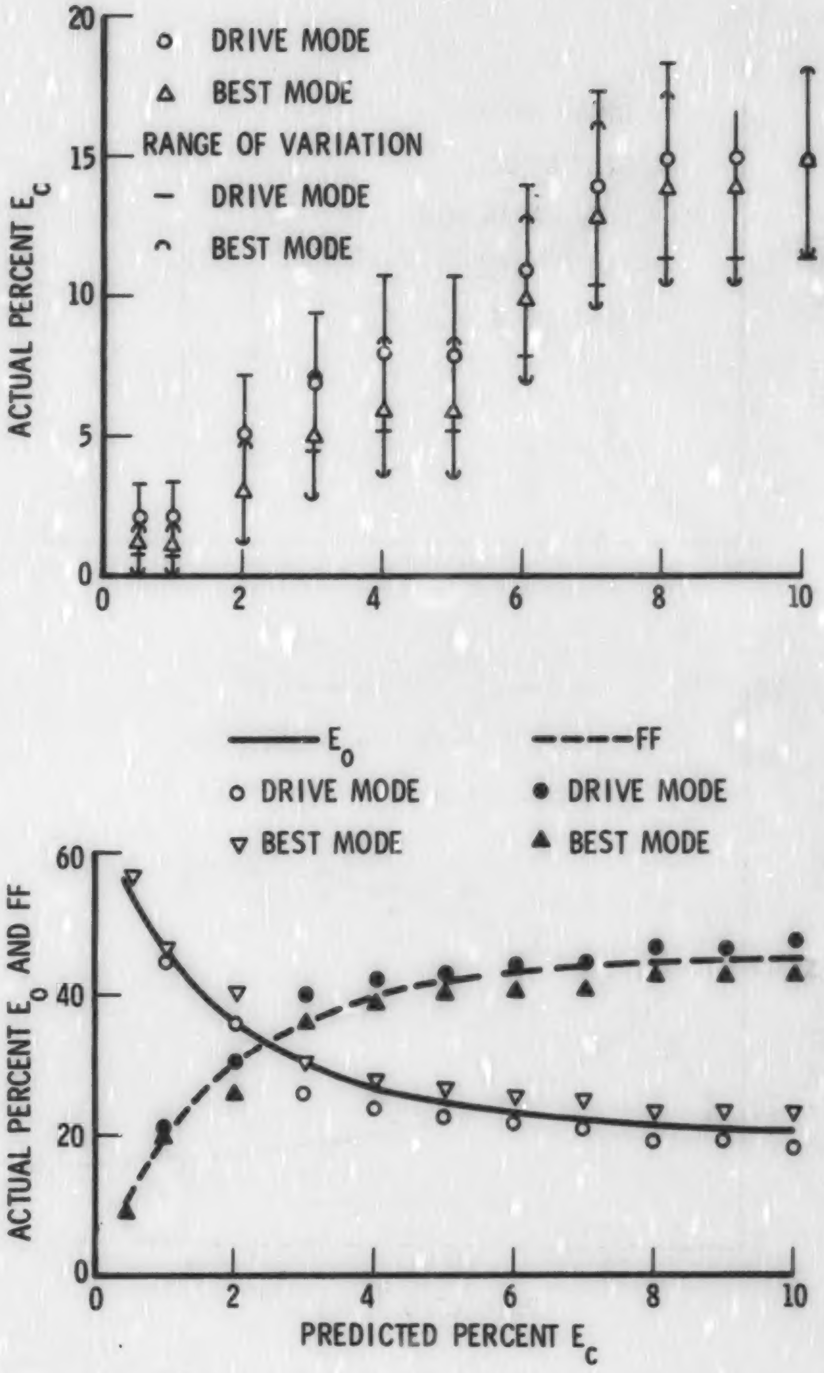


Figure 30. Variation of Actual E_C, E_O, and FF with Predicted E_C; Federal Three-Mode; Chicago

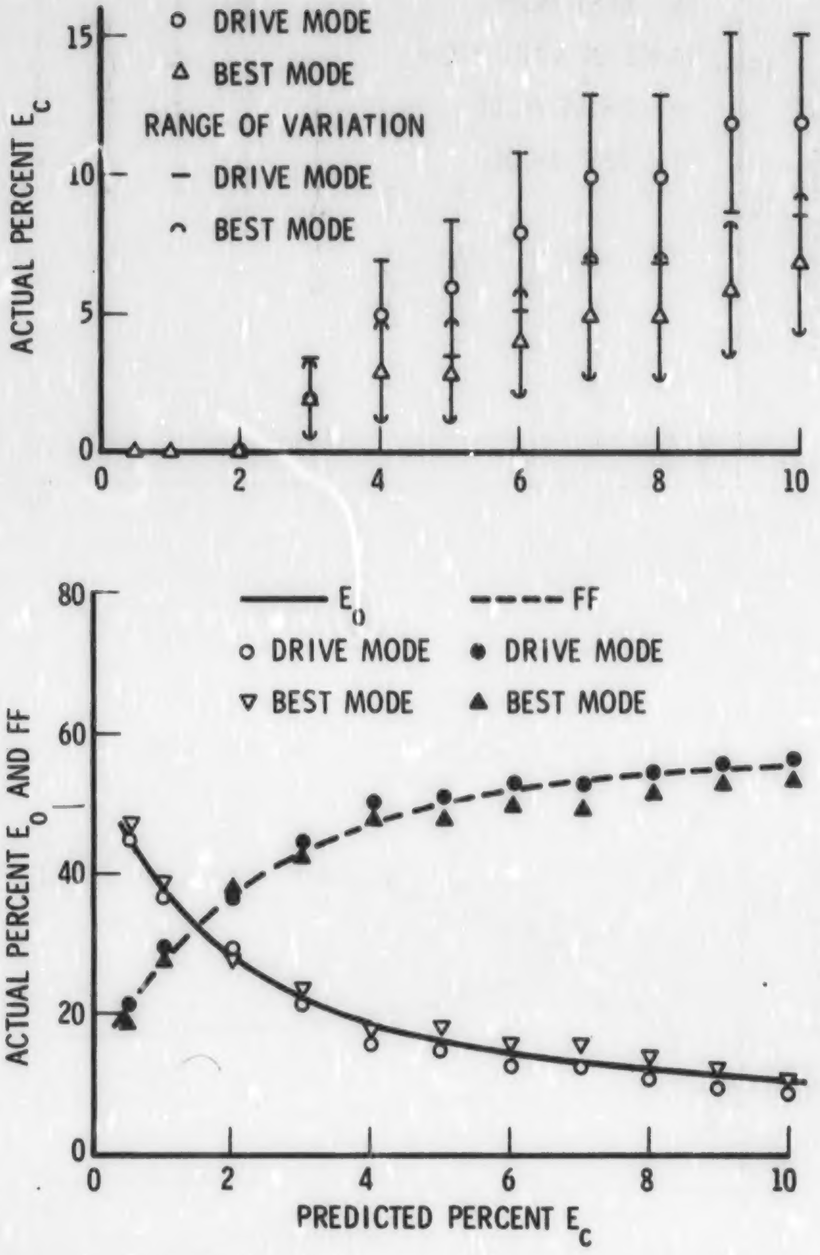


Figure 31. Variation of Actual E_c, E_0, and FF with Predicted E_c; Federal Three-Mode; Houston

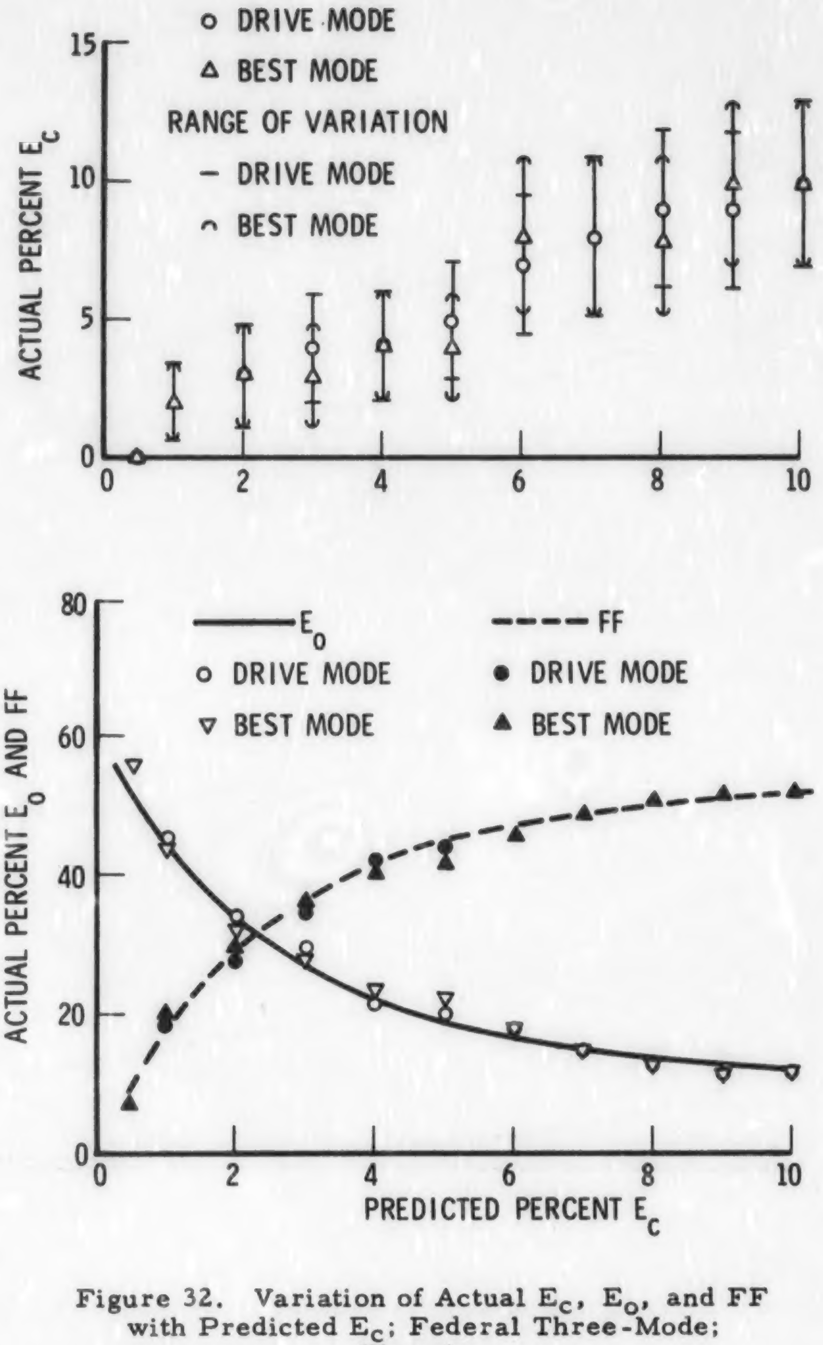


Figure 32. Variation of Actual E_c, E_o, and FF with Predicted E_c; Federal Three-Mode; Phoenix

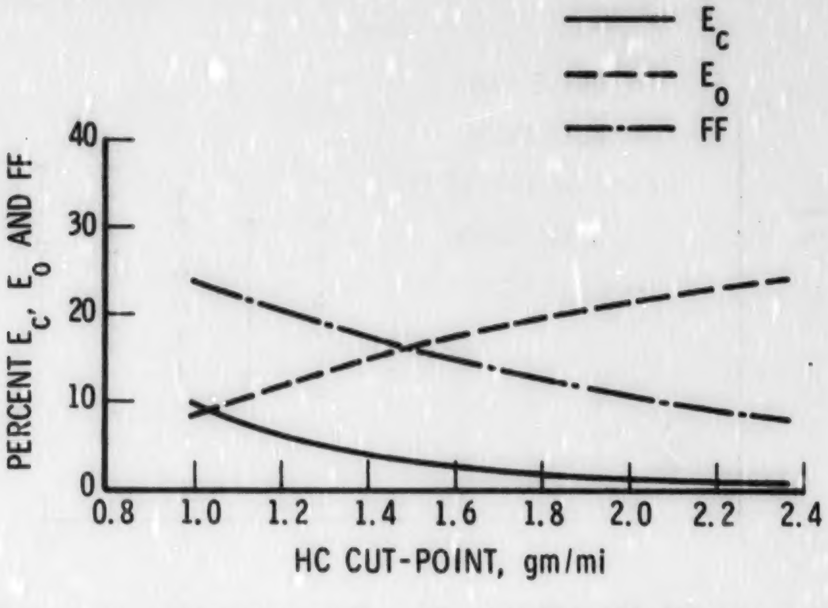


Figure 33. Variation of E_c, E_o, and FF with HC Cut-point; 150 CID and Less; Federal Short Cycle; Bounded Errors of Commission Method

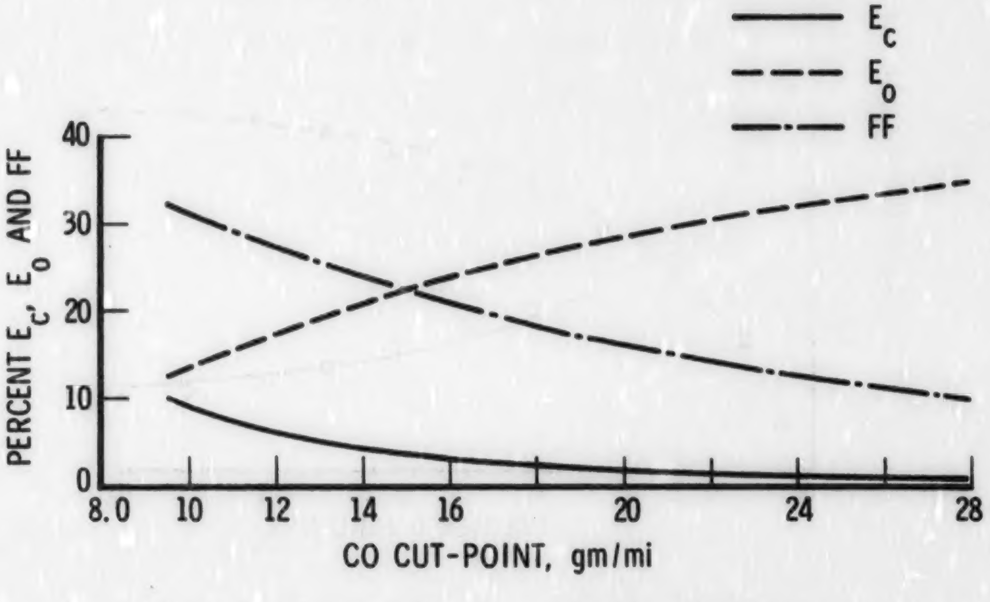


Figure 34. Variation of E_c, E_o, and FF with CO Cut-point; 150 CID and Less; Federal Short Cycle; Bounded Errors of Commission Method

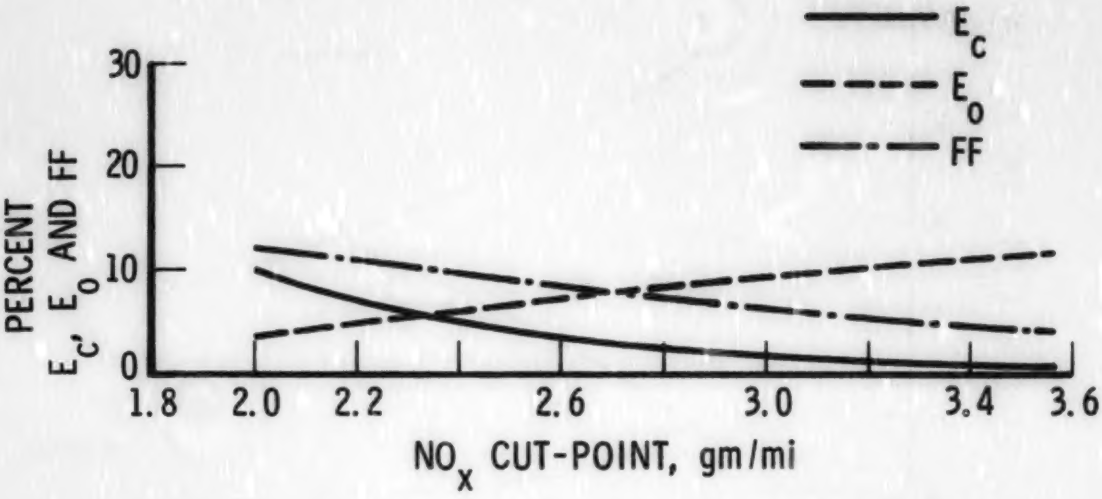


Figure 35. Variation of E_c, E_o, and FF with NO_x Cut-point; 150 CID and Less; Federal Short Cycle; Bounded Errors of Commission Method

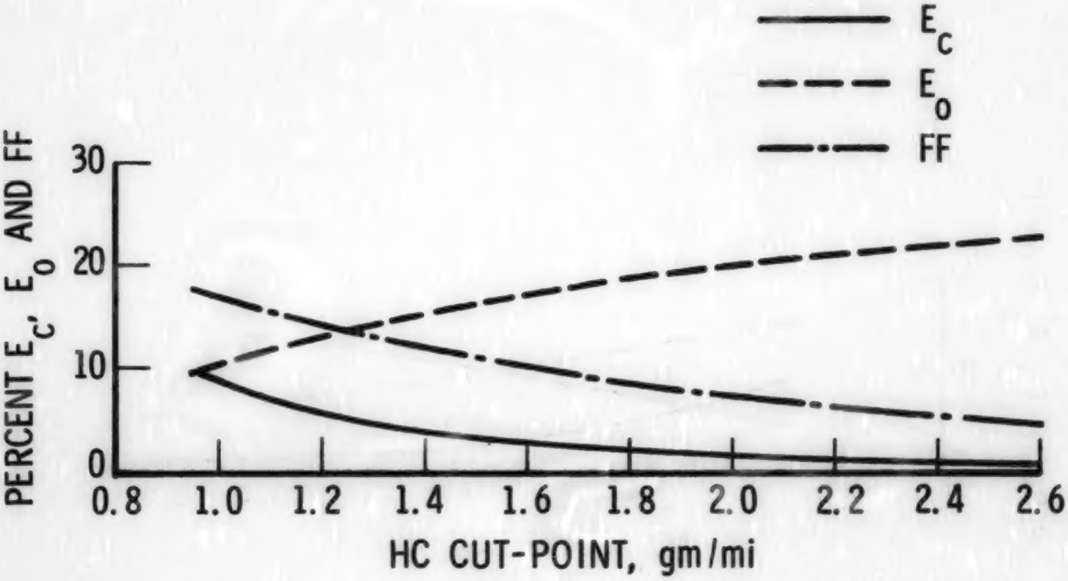


Figure 36. Variation of E_c, E_o, and FF with HC Cut-point; 151 to 259 CID; Federal Short Cycle; Bounded Errors of Commission Method

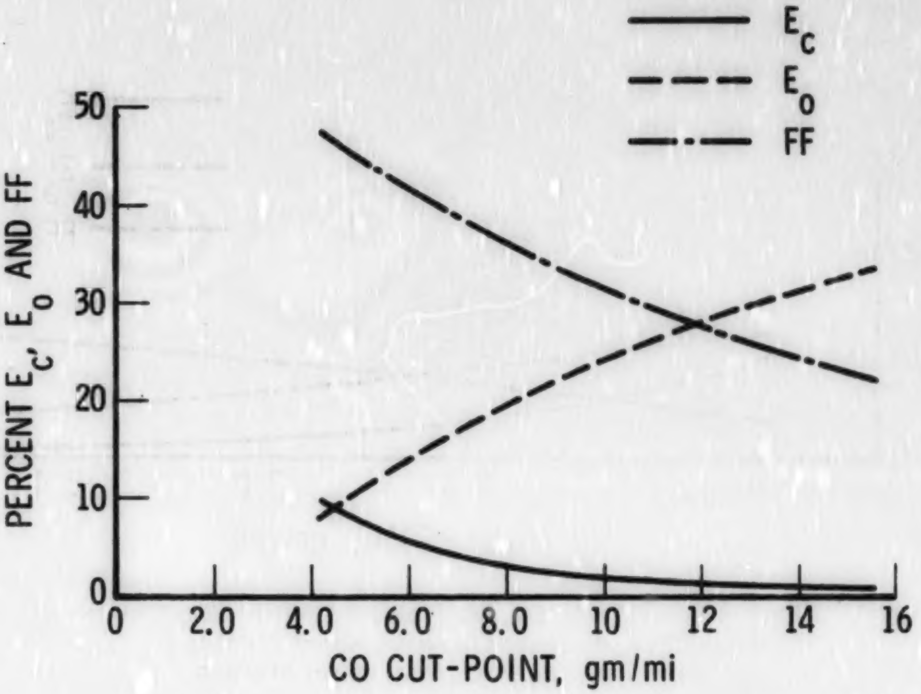


Figure 37. Variation of E_c, E_o, and FF with CO Cut-point; 151 to 259 CID; Federal Short Cycle; Bounded Errors of Commission Method

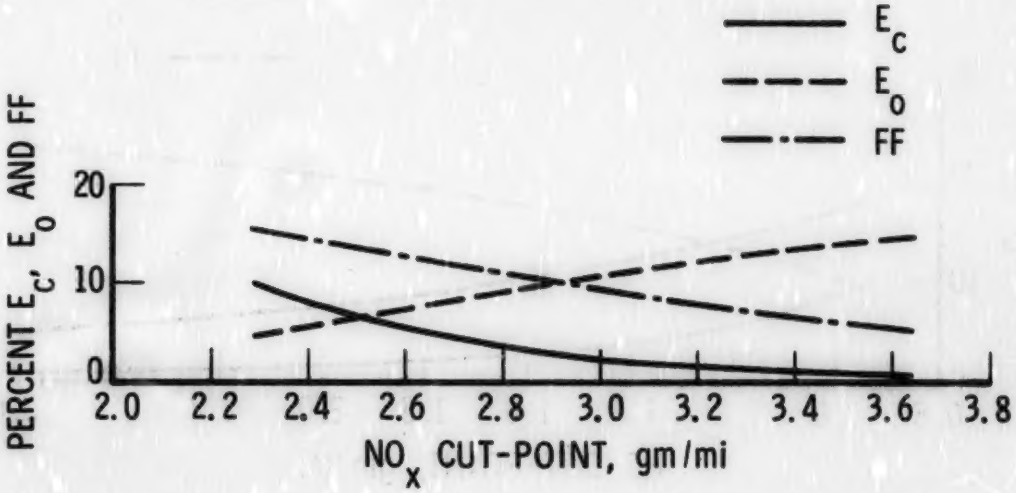


Figure 38. Variation of E_c, E_o, and FF with NO_x Cut-point; 151 to 259 CID; Federal Short Cycle; Bounded Errors of Commission Method

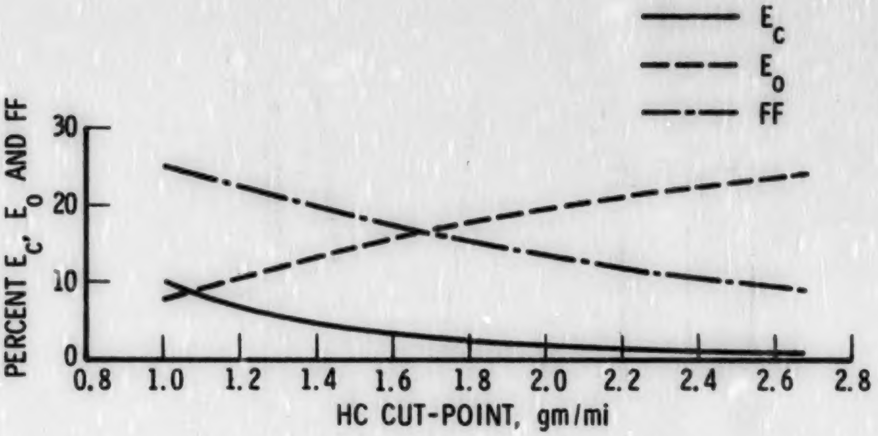


Figure 39. Variation of E_c, E_o, and FF with HC Cut-point; 260 CID and Greater, Federal Short Cycle; Bounded Errors of Commission Method

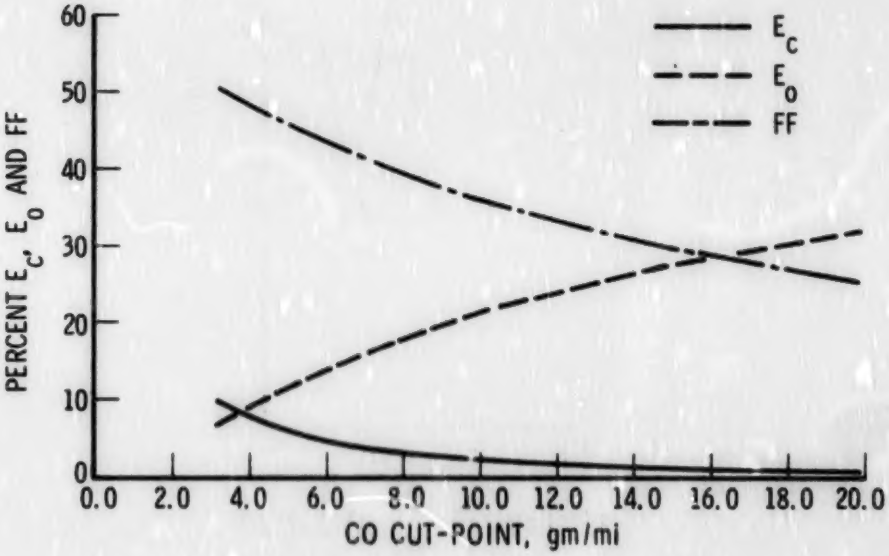


Figure 40. Variation of E_c, E_o, and FF with CO Cut-point; 260 CID and Greater; Federal Short Cycle; Bounded Errors of Commission Method

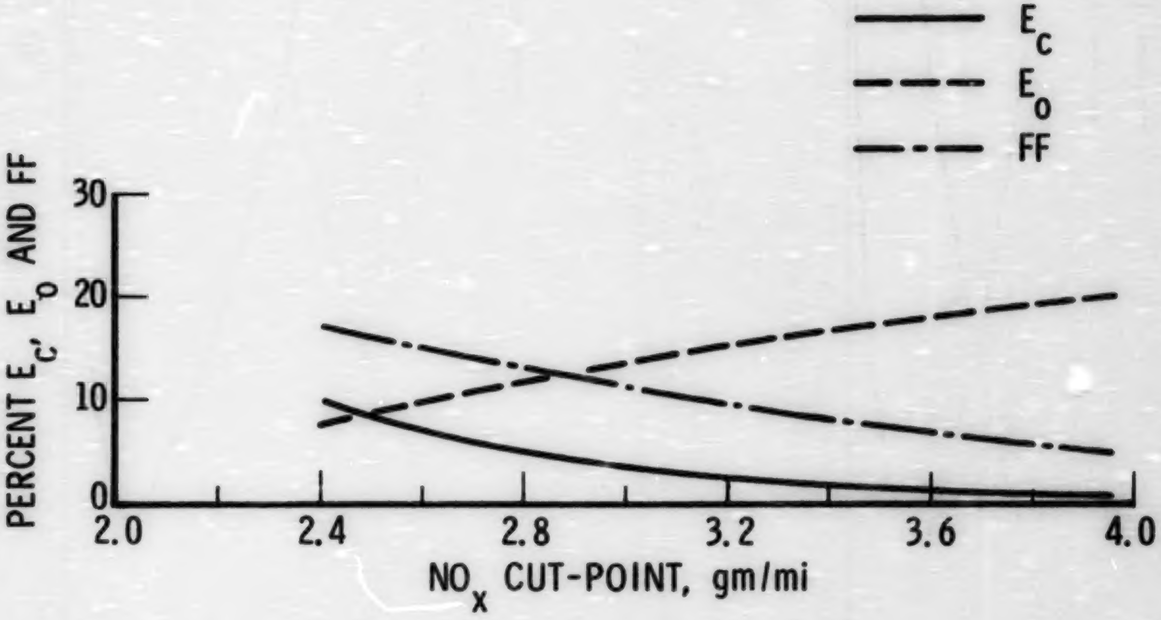


Figure 41. Variation of E_c, E_o, and FF with NO_x Cut-point; 260 CID and Greater; Federal Short Cycle; Bounded Errors of Commission Method

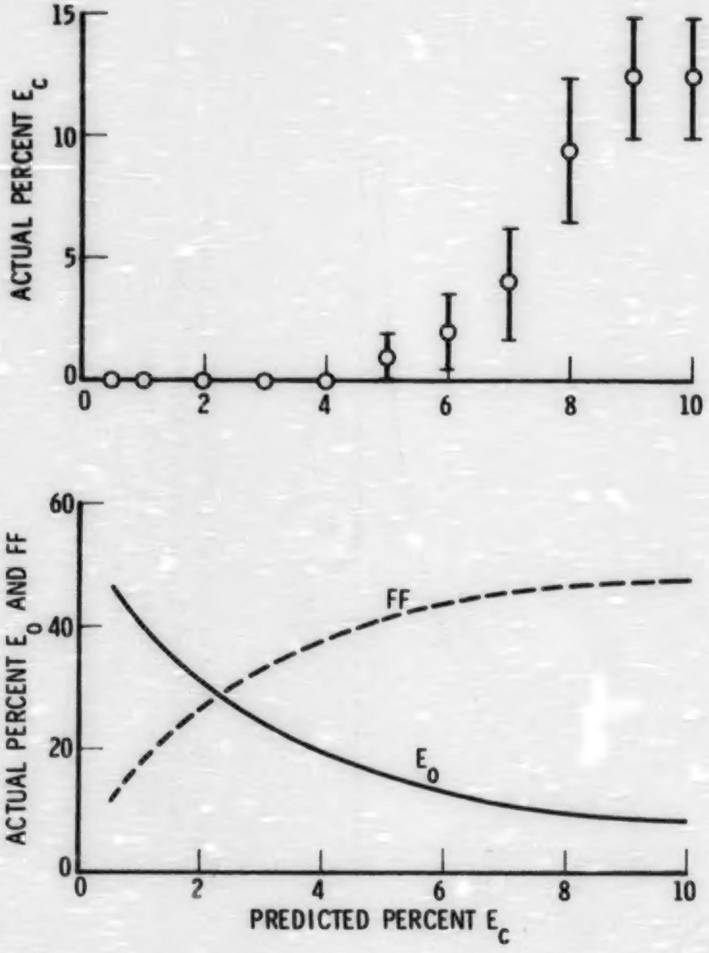


Figure 42. Variation of Actual E_c, E_o, and FF with Predicted E_c, Federal Short Cycle; All Three Cities; Engine Displacement 150 CID and Less

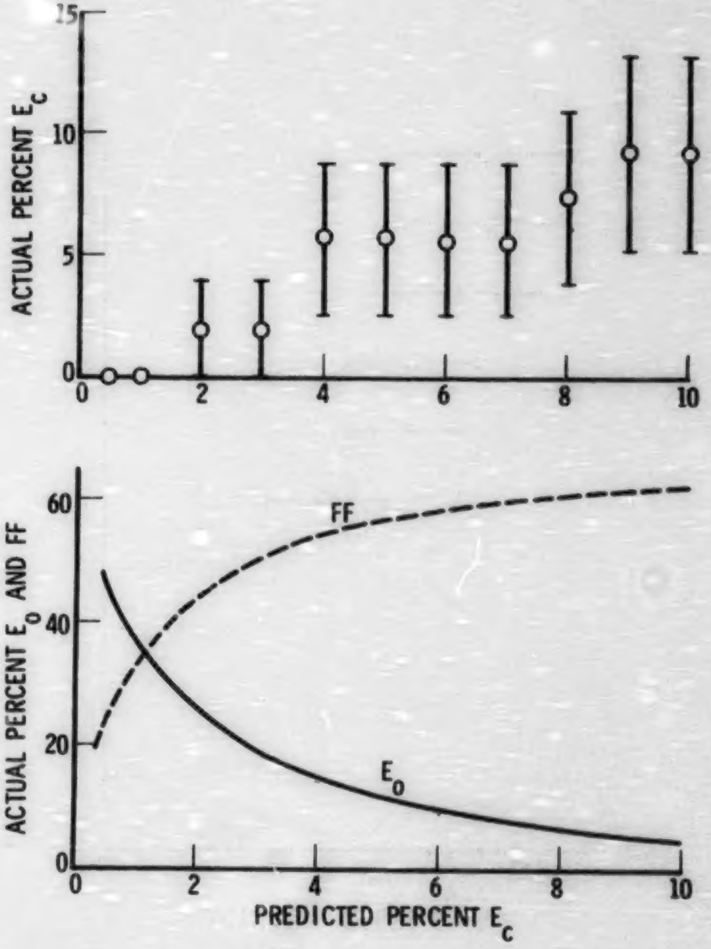


Figure 43. Variation of Actual E_c, E_o, and FF with Predicted E_c, Federal Short Cycle; All Three Cities; Engine Displacement 151 to 259 CID

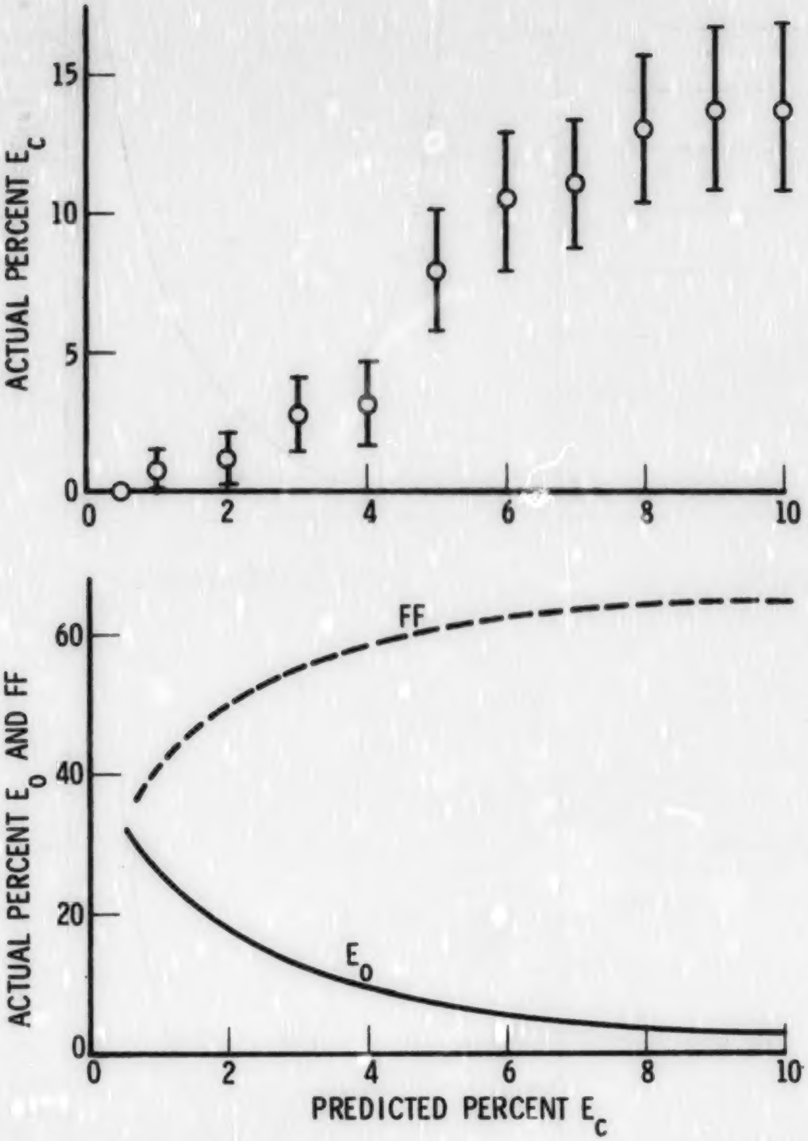


Figure 44. Variation of Actual E_c, E_o, and FF with Predicted E_c; Federal Short Cycle; All Three Cities; Engine Displacement 260 CID and Greater

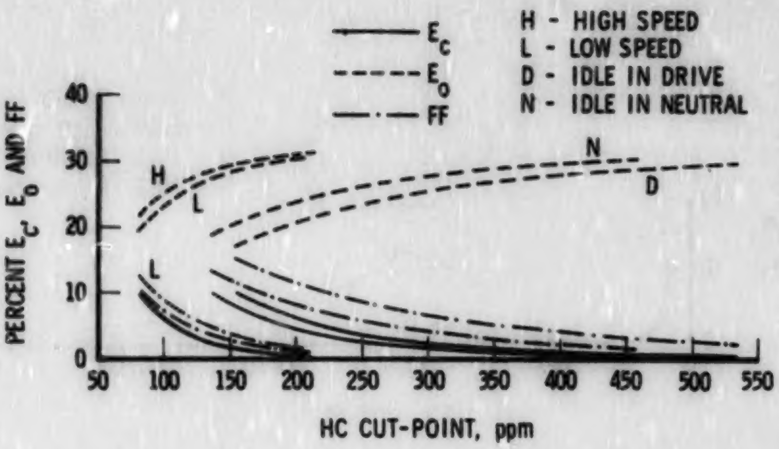


Figure 45. Variation of E_c, E_o, and FF with HC Cut-point; 150 CID and Less; Federal Three-Mode; Bounded Errors of Commission Method

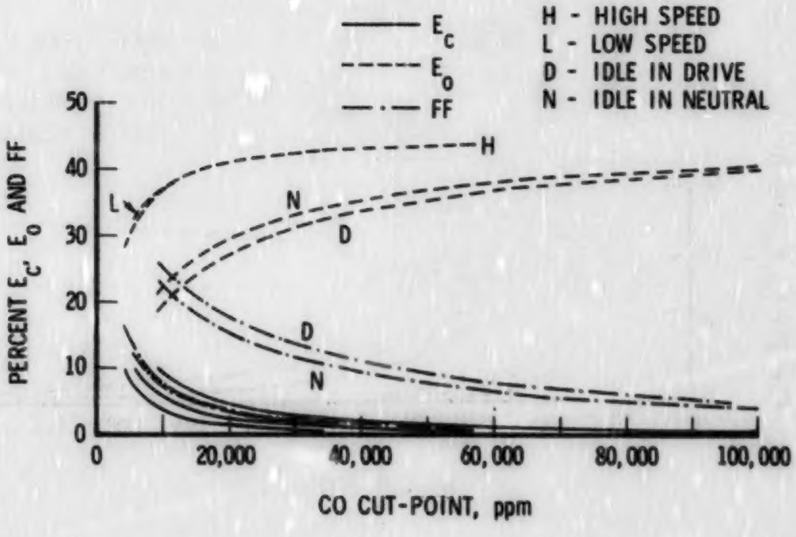


Figure 46. Variation of E_c, E_o, and FF with CO Cut-point; 150 CID and Less; Federal Three-Mode; Bounded Errors of Commission Method

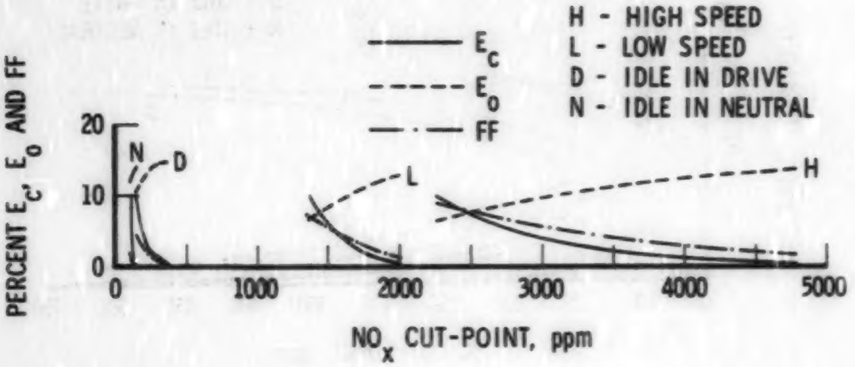


Figure 47. Variation of E_C, E_O, and FF with NO_x Cut-point; 150 CID and Less Federal Three-Mode; Bounded Errors of Commission Method

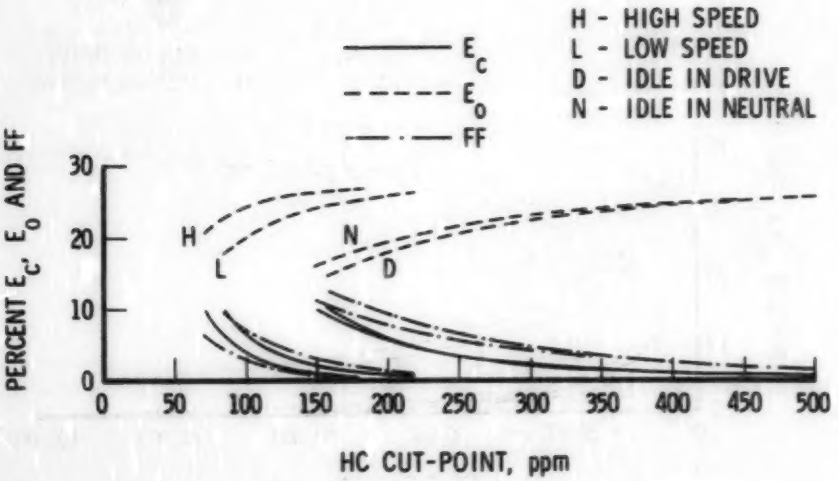


Figure 48. Variation of E_C, E_O, and FF with HC Cut-point; 151 to 259 CID; Federal Three-Mode; Bounded Errors of Commission Method

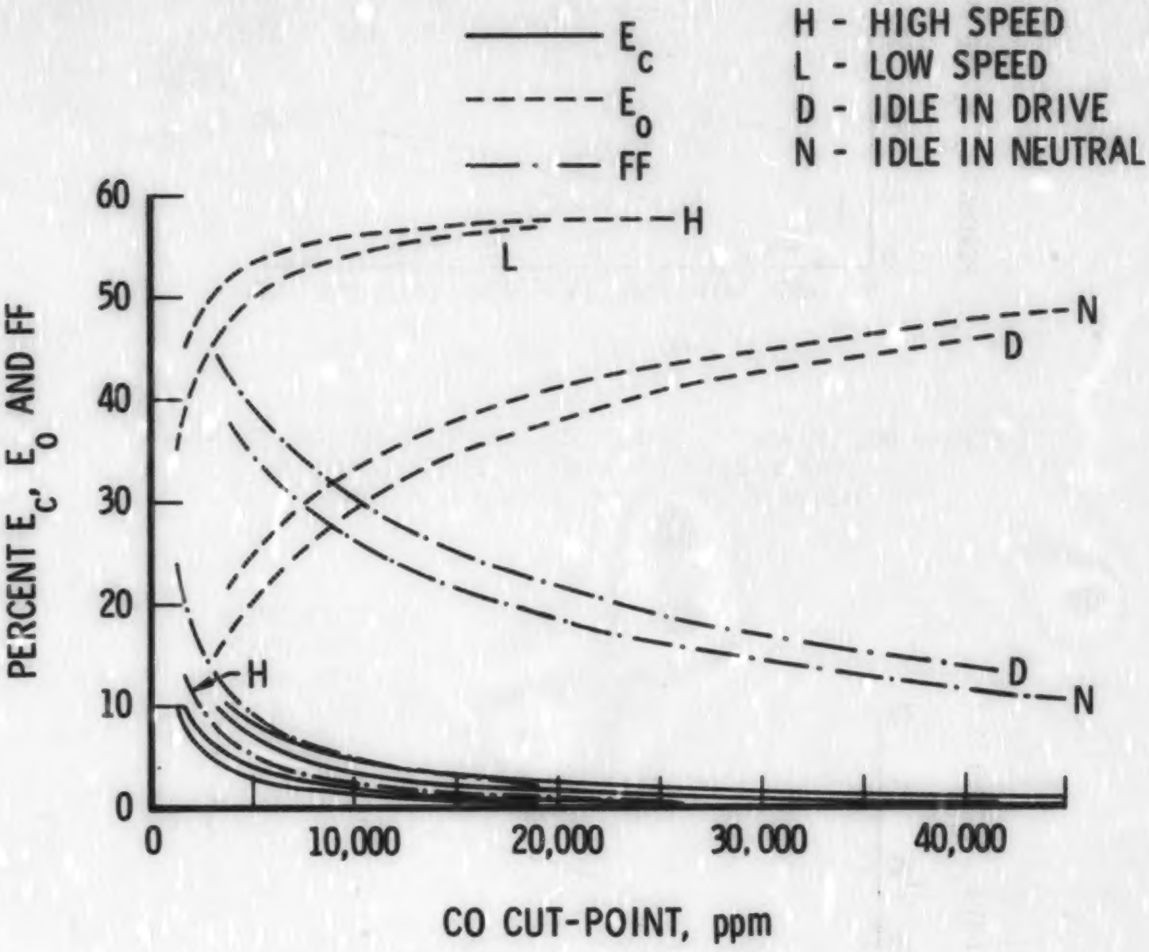


Figure 49. Variation of E_c, E_o, and FF with CO Cut-point; 151 to 259 CID; Federal Three-Mode; Bounded Errors of Commission Method

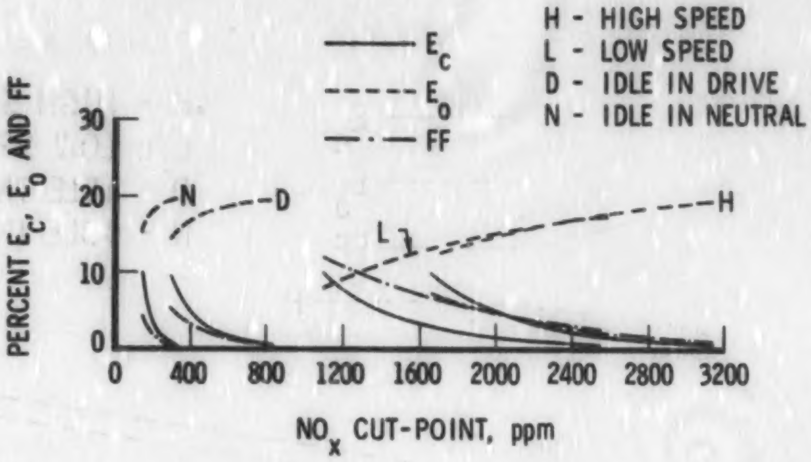


Figure 50. Variation of E_c, E_o, and FF with NO_x Cut-point; 151 to 259 CID; Federal Three-Mode; Bounded Errors of Commission Method

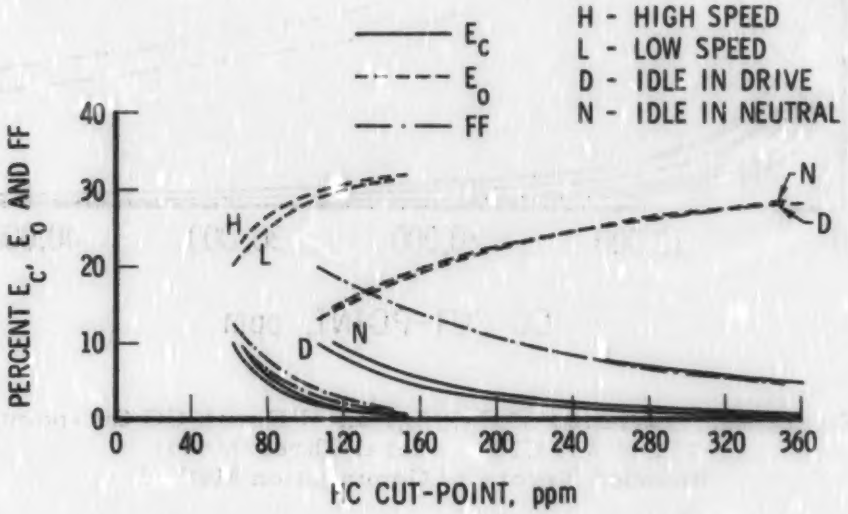


Figure 51. Variation of E_c, E_o, and FF with HC Cut-point; 260 CID and Greater, Federal Three-Mode; Bounded Errors of Commission Method

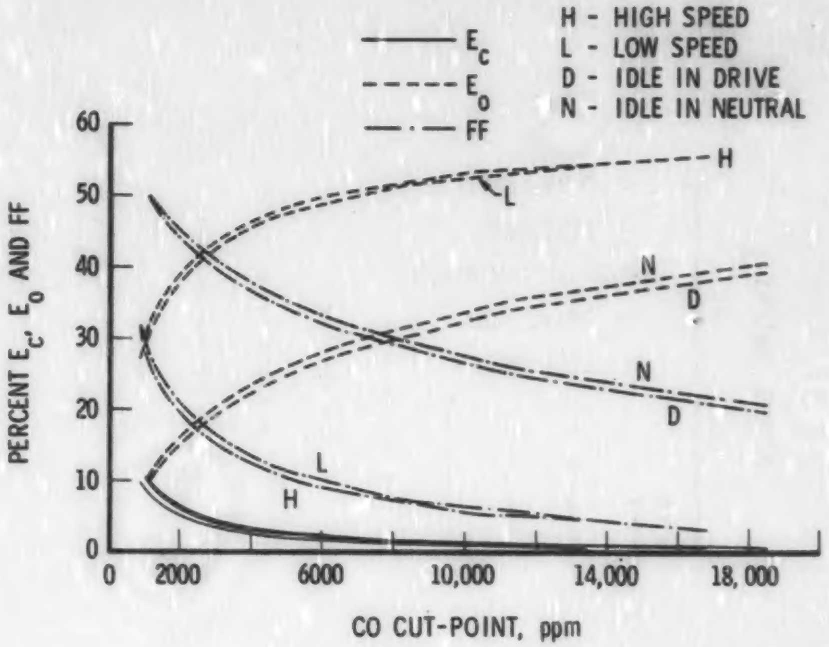


Figure 52. Variation of E_c, E_o, and FF with CO Cut-point; 260 CID and Greater; Federal Three-Mode; Bounded Errors of Commission Method

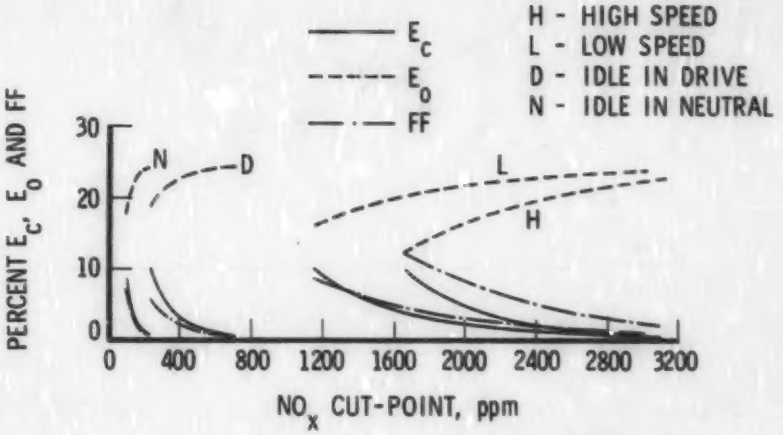


Figure 53. Variation of E_c, E_o, and FF with NO_x Cut-point; 260 CID and Greater; Federal Three-Mode; Bounded Errors of Commission Method

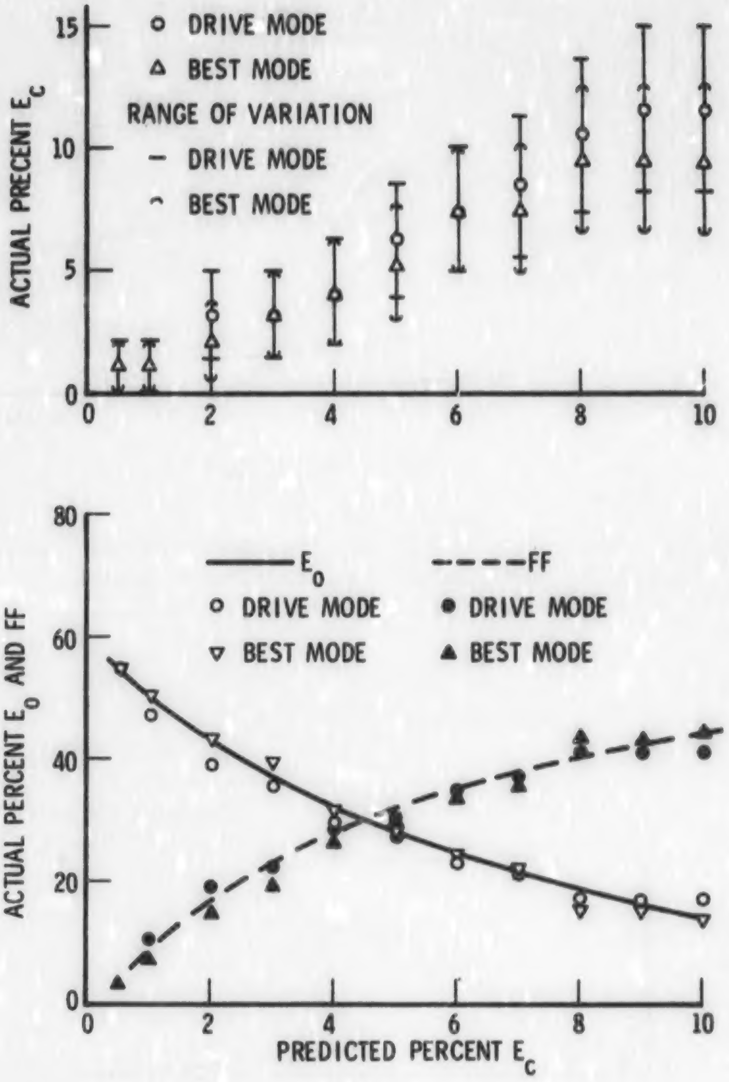


Figure 54. Variation of Actual E_c, E_O, and FF with Predicted E_c; Federal Three-Mode; All Three Cities; Engine Displacement 150 CID and Less

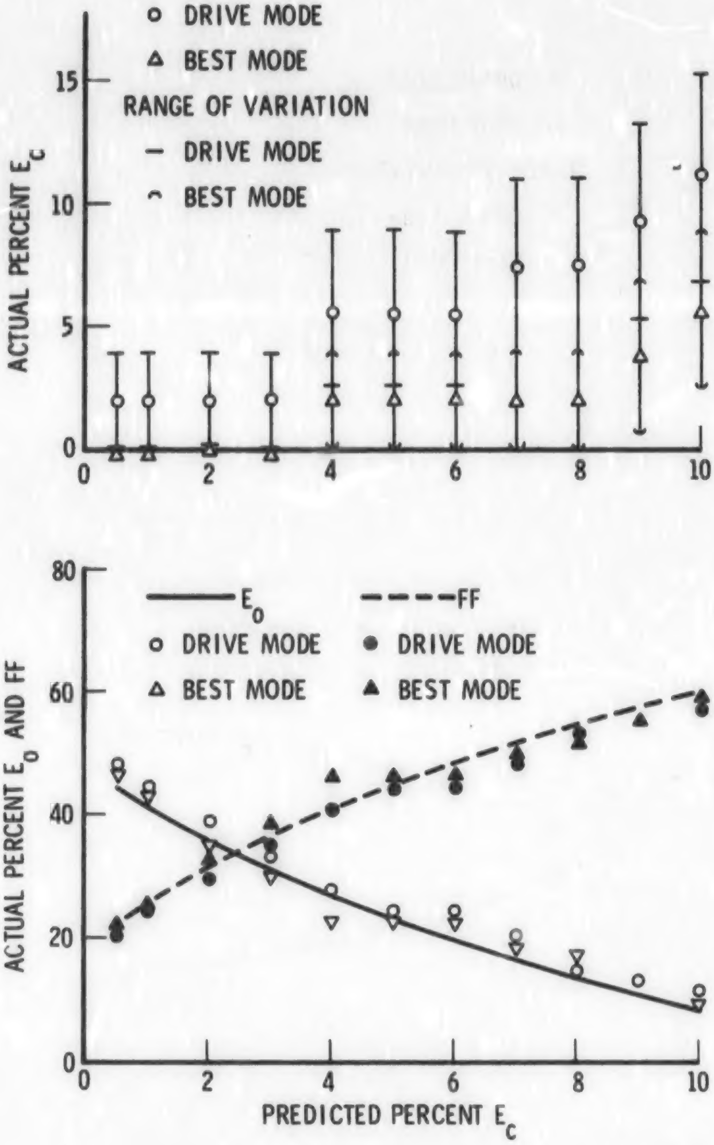


Figure 55. Variation of Actual E_C, E_O, and FF with Predicted E_C; Federal Three-Mode; All Three Cities; Engine Displacement 151 to 259 CID

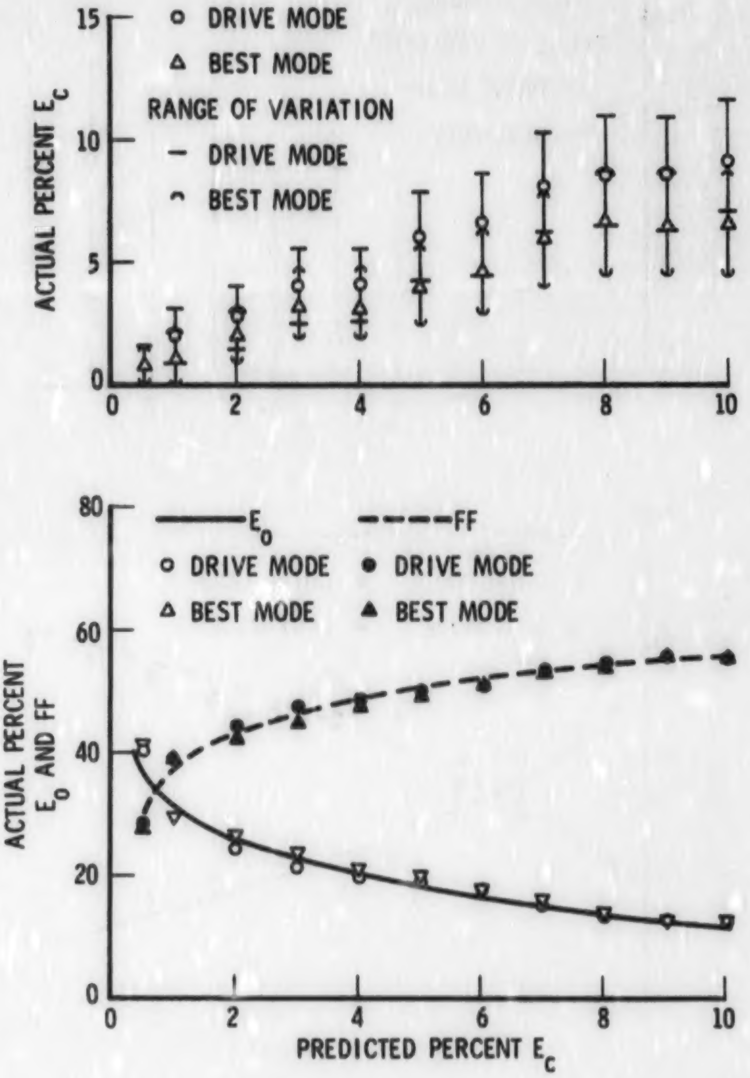


Figure 56. Variation of Actual E_C, E_O, and FF with Predicted E_C; Federal Three-Mode; All Three Cities; Engine Displacement 260 CID and Greater

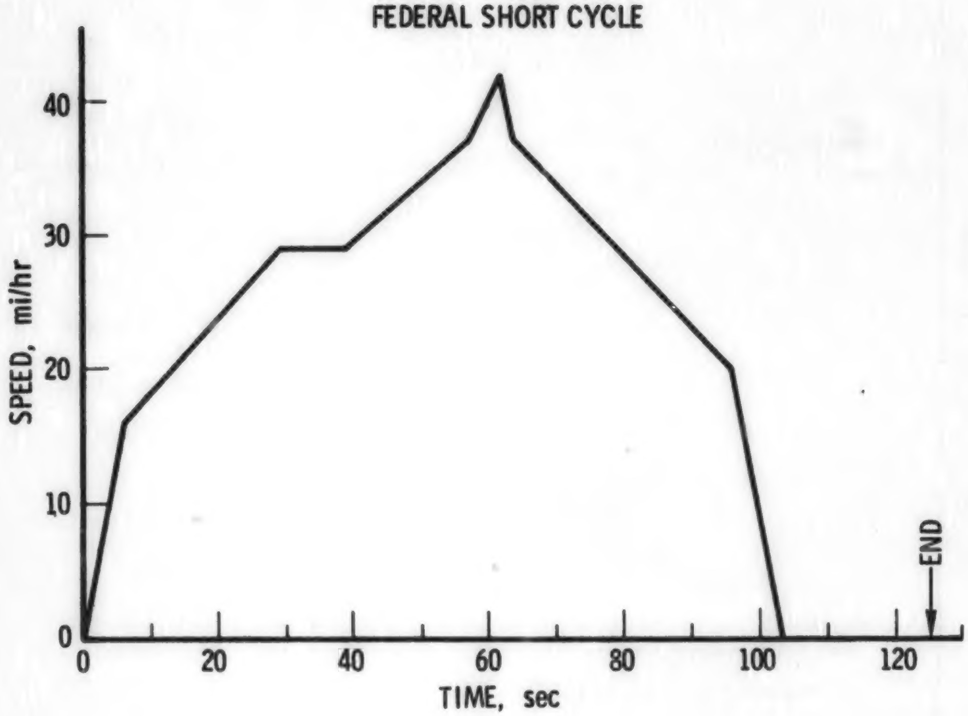
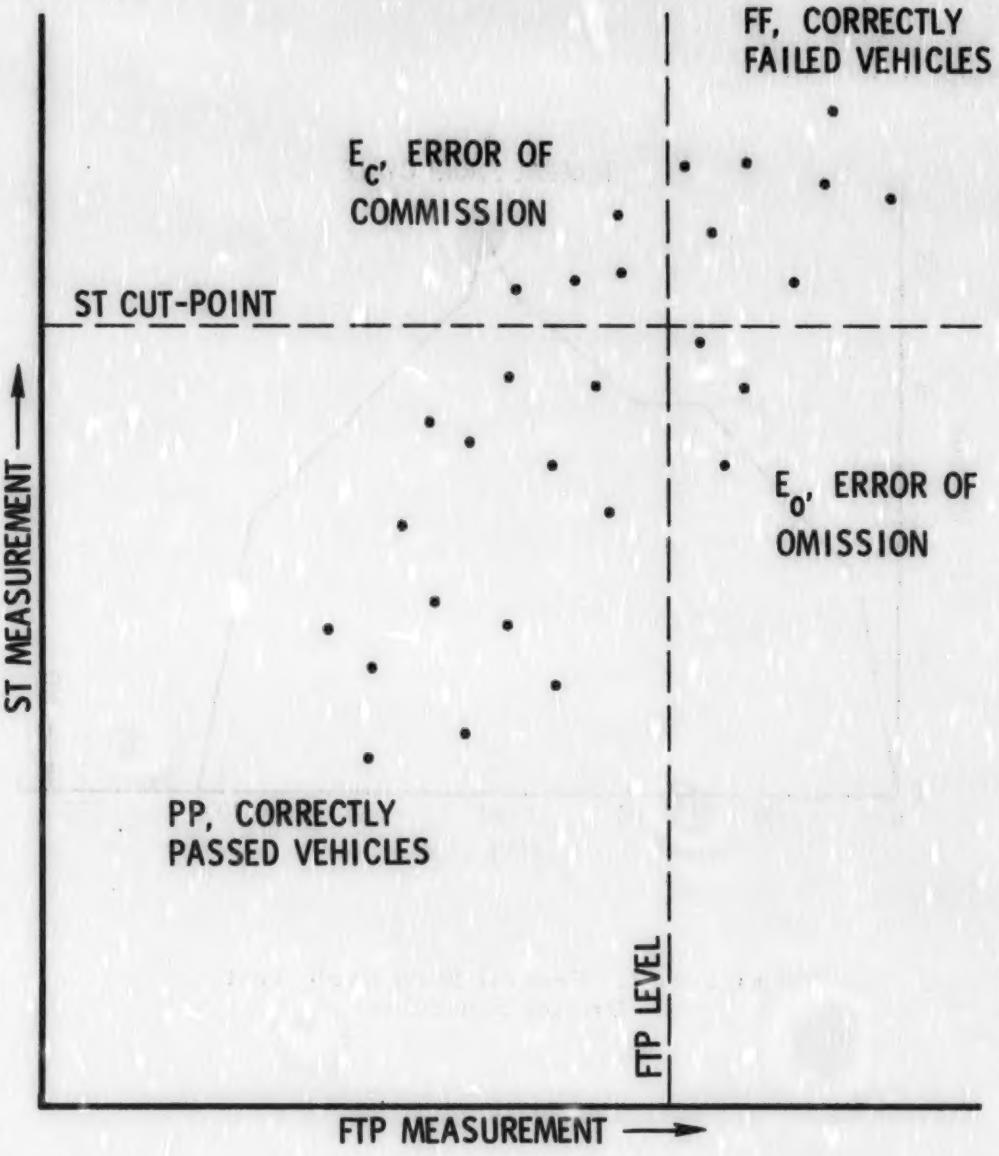
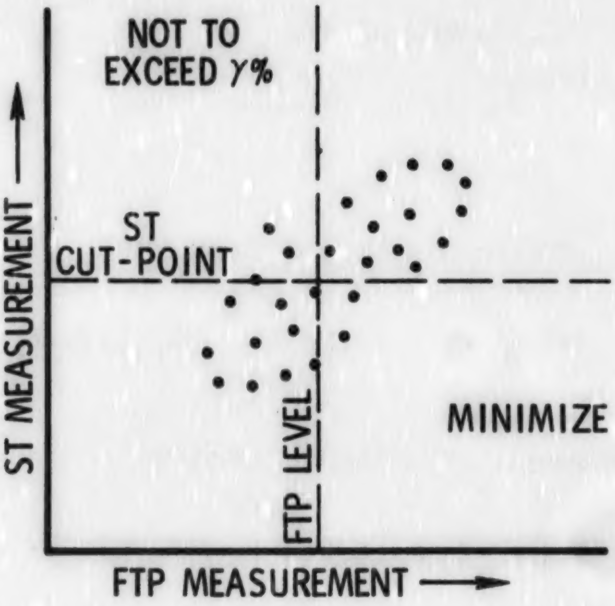


Figure 57. Federal Short Cycle Test Driving Schedules



FF, CORRECTLY FAILED VEHICLES
E$_C$, ERROR OF COMMISSION
ST CUT-POINT
ST MEASUREMENT →
E$_O$, ERROR OF OMISSION
PP, CORRECTLY PASSED VEHICLES
FTP LEVEL
FTP MEASUREMENT →

Figure 58. Contingency Table Representation



MINIMIZE E_O SUBJECT TO $E_C \leq \gamma\%$

NOT TO
EXCEED γ%
ST
CUT-POINT
MINIMIZE
FTP LEVEL
ST MEASUREMENT
FTP MEASUREMENT

Figure 59. Bounded Errors of Commission Method

BIVARIATE NORMAL DISTRIBUTION

$$D(X_1, X_2) = \frac{e^{-\left\{\frac{1}{2(1-\rho^2)}\left[\left(\frac{X_1-\mu_1}{\sigma_1}\right)^2 - 2\rho\left(\frac{X_1-\mu_1}{\sigma_1}\right)\left(\frac{X_2-\mu_2}{\sigma_2}\right) + \left(\frac{X_2-\mu_2}{\sigma_2}\right)^2\right]\right\}}}{2\pi\sigma_1\sigma_2\sqrt{1-\rho^2}}$$

WHERE μ_1, μ_2 = POPULATION MEANS

σ_1, σ_2 = POPULATION STANDARD DEVIATIONS

ρ = CORRELATION COEFFICIENT

X_1 = FTP MEASUREMENT

X_2 = ST MEASUREMENT

Figure 60. Parametric Model

PROBABILITY OF ERROR OF COMMISSION

$$\Pr\{X_1 \le C_1, X_2 > C_2\} = \int_{-\infty}^{C_1}\int_{C_2}^{\infty} D(X_1, X_2)\, dX_1 dX_2$$

PROBABILITY OF ERROR OF OMISSION

$$\Pr\{X_1 > C_1, X_2 \le C_2\} = \int_{C_1}^{+\infty}\int_{-\infty}^{C_2} D(X_1, X_2)\, dX_1 dX_2$$

PROBABILITY OF CORRECT FAILURES

$$\Pr\{X_1 > C_1, X_2 > C_2\} = \int_{C_1}^{+\infty}\int_{C_2}^{+\infty} D(X_1, X_2)\, dX_1 dX_2$$

WHERE C_1 = FTP STANDARD

C_2 = ST CUT-POINT

Figure 61. Probability Equations

Bounded Errors of Commission: Solve for C_2

$$\gamma = \int_{-\infty}^{C_1}\int_{C_2}^{\infty} D(X_1, X_2)\, dX_1 dX_2$$

where

C_1 = FTP Standard
C_2 = ST Cut-Point
γ = Maximum allowable probability of an error of commission
D(.,.) = Statistical model as determined by the data

Figure 62. Equations for ST Cut-Point Determination

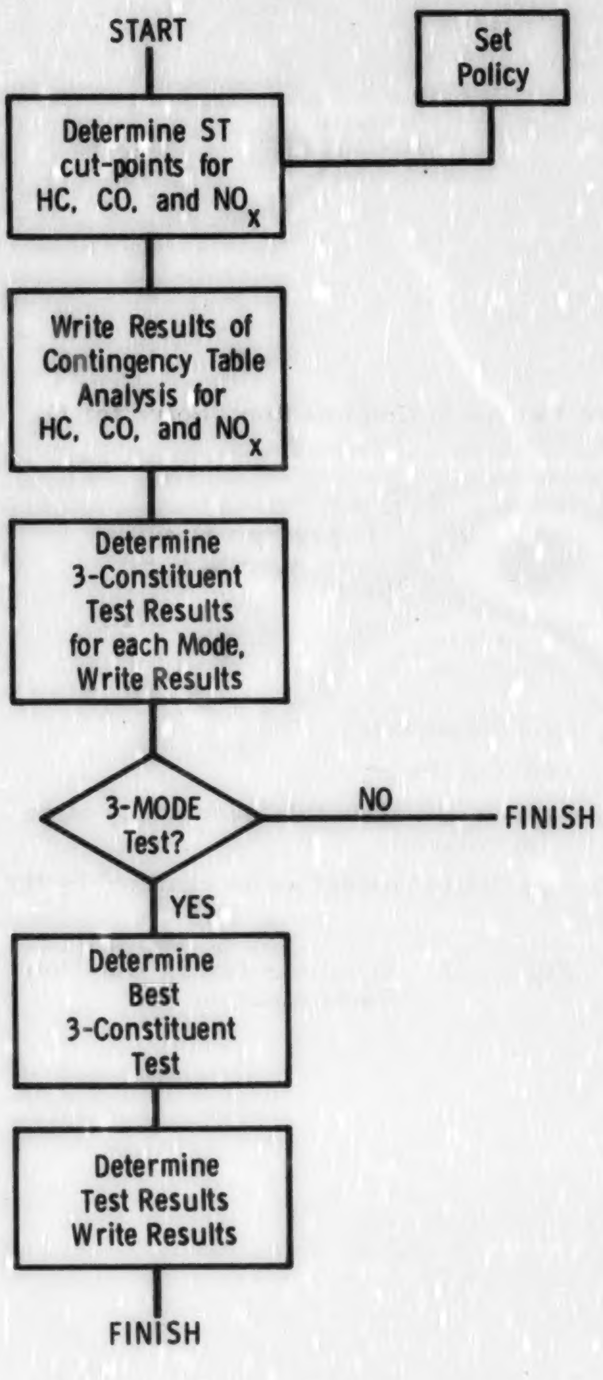

START
Set Policy
Determine ST cut-points for HC, CO, and NOx
Write Results of Contingency Table Analysis for HC, CO, and NOx
Determine 3-Constituent Test Results for each Mode, Write Results
3-MODE Test?
NO
FINISH
YES
Determine Best 3-Constituent Test
Determine Test Results Write Results
FINISH

Figure 63. Computation Flow Chart

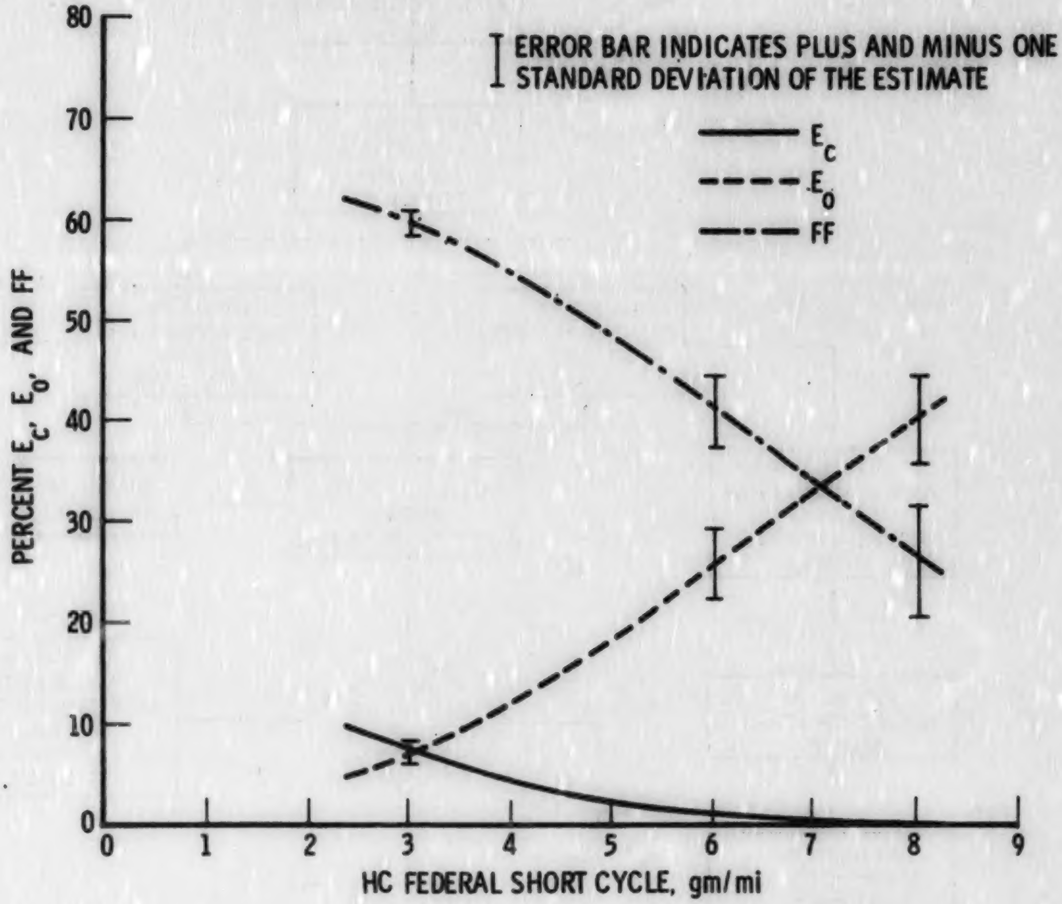


Figure 64. Typical Variability of Predicted Population Results

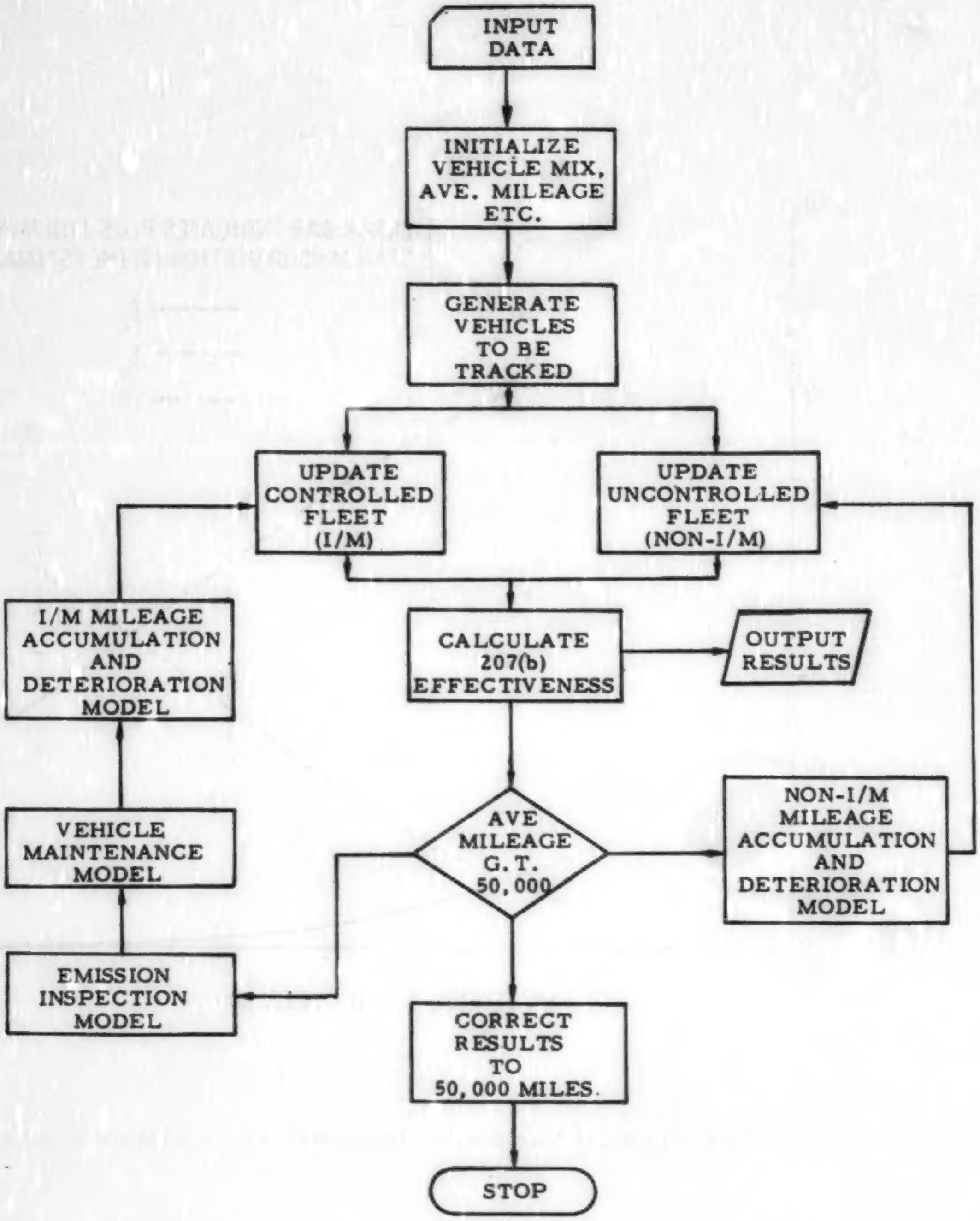

INPUT DATA
INITIALIZE VEHICLE MIX, AVE. MILEAGE ETC.
GENERATE VEHICLES TO BE TRACKED
UPDATE CONTROLLED FLEET (I/M)
UPDATE UNCONTROLLED FLEET (NON-I/M)
I/M MILEAGE ACCUMULATION AND DETERIORATION MODEL
CALCULATE 207(b) EFFECTIVENESS
OUTPUT RESULTS
VEHICLE MAINTENANCE MODEL
AVE MILEAGE G.T. 50,000
NON-I/M MILEAGE ACCUMULATION AND DETERIORATION MODEL
EMISSION INSPECTION MODEL
CORRECT RESULTS TO 50,000 MILES.
STOP

Figure 65. Logical Flow Chart for 207(b) Effectiveness Estimation

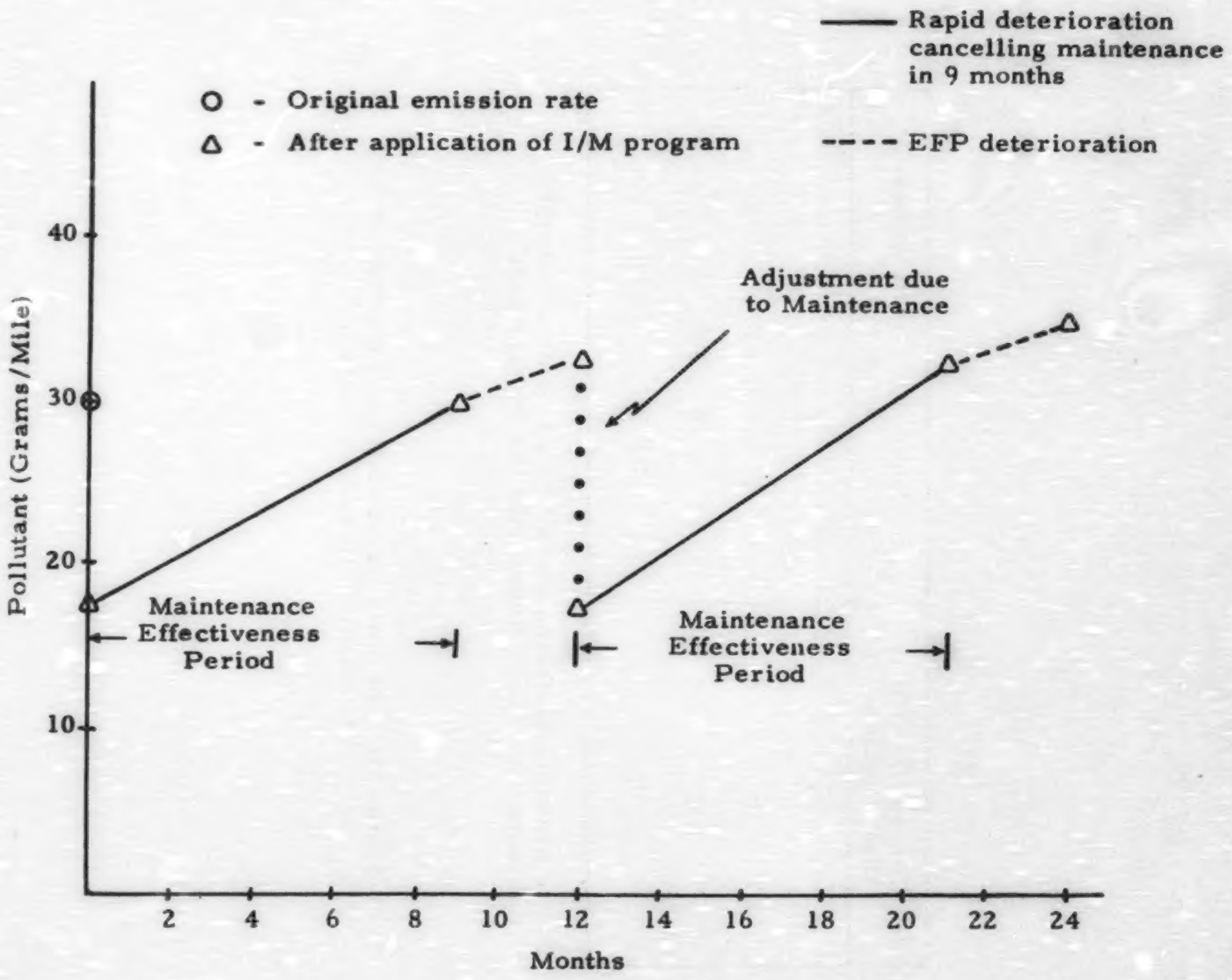


Figure 66. Piecewise Linear Deterioration for FF Vehicles Shown Over Two-Year Period

Current Year's Classification	Possible Classifications Next Year[a]
FF	E_o, FF
E_o	E_o, FF
E_c	E_o, FF
PP	PP, E_c, E_o, FF

[a] The probability of each classification is determined by the inspection model based upon the 300-car data

Figure 67. Vehicle Classification Properties of the 207(b) Effectiveness Simulator

GLOSSARY

CID	cubic inch displacement
CO	carbon monoxide
CVS	constant volume sampling
E_c	error of commission
EFP	Emission Factors Program
E_o	error of ommision
FF	vehicles failed by both the ST and the FTP
FTP	Federal Test Procedure
HC	hydrocarbon
I/M	inspection and maintenance
NO_x	oxides of nitrogen
PP	vehicles passed by both the ST and the FTP
ST	short test
STE	short test effectiveness
STRR	short test rejection ratio
207(b)	reference to section 207(b) of the 1970 Clean Air Act